



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

|   |  |    |  |
|---|--|----|--|
| (51) International Patent Classification <sup>7</sup> :<br><br>C07K 14/315, 16/12, C07H 19/00, C12N 1/20, C12Q 1/68, A61K 35/74, 39/09  |  | A1 | (11) International Publication Number: <b>WO 00/39159</b>  |
|   |  |    | (43) International Publication Date: 6 July 2000 (06.07.00)  |
| (21) International Application Number: PCT/NZ99/00228   |  |    | (81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). |
| (22) International Filing Date: 24 December 1999 (24.12.99)   |  |    |  |
| (30) Priority Data:<br>333589 24 December 1998 (24.12.98) NZ  |  |    |  |
| (71) Applicant ( <i>for all designated States except US</i> ): AUCKLAND UNISERVICES LIMITED [NZ/NZ]; 58 Symonds Street, Auckland (NZ).  |  |    |  |
| (72) Inventors; and   |  |    |  |
| (75) Inventors/Applicants ( <i>for US only</i> ): FRASER, John, David [NZ/NZ]; Auckland UniServices Limited, UniServices House, 58 Symonds Street, Auckland (NZ). PROFT, Thomas [NZ/NZ]; Auckland UniServices Limited, UniServices House, 58 Symonds Street, Auckland (NZ). |  |    |  |
| (74) Agents: BENNETT, Michael, Roy et al.; West-Walker Bennett, Mobil on the Park, 157 Lambton Quay, Wellington (NZ).   |  |    |  |
| (54) Title: SUPERANTIGENS   |  |    |  |
| (57) Abstract   |  |    |  |
| The invention provides superantigens SMEZ-2, SPE-G, SPE-H and SPE-J, as well as polynucleotides which encode them. Such superantigens have, <i>inter alia</i> , diagnostic and therapeutic applications.  |  |    |  |

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

|    |                          |    |                                       |    |   |    |                          |
|----|--------------------------|----|---------------------------------------|----|---|----|--------------------------|
| AL | Albania                  | ES | Spain                                 | LS | Lesotho                                   | SI | Slovenia                 |
| AM | Armenia                  | FI | Finland                               | LT | Lithuania                                 | SK | Slovakia                 |
| AT | Austria                  | FR | France                                | LU | Luxembourg                                | SN | Senegal                  |
| AU | Australia                | GA | Gabon                                 | LV | Latvia                                    | SZ | Swaziland                |
| AZ | Azerbaijan               | GB | United Kingdom                        | MC | Monaco                                    | TD | Chad                     |
| BA | Bosnia and Herzegovina   | GE | Georgia                               | MD | Republic of Moldova                       | TG | Togo                     |
| BB | Barbados                 | GH | Ghana                                 | MG | Madagascar                                | TJ | Tajikistan               |
| BE | Belgium                  | GN | Guinea                                | MK | The former Yugoslav Republic of Macedonia | TM | Turkmenistan             |
| BF | Burkina Faso             | GR | Greece                                | ML | Mali                                      | TR | Turkey                   |
| BG | Bulgaria                 | HU | Hungary                               | MN | Mongolia                                  | TT | Trinidad and Tobago      |
| BJ | Benin                    | IE | Ireland                               | MR | Mauritania                                | UA | Ukraine                  |
| BR | Brazil                   | IL | Israel                                | MW | Malawi                                    | UG | Uganda                   |
| BY | Belarus                  | IS | Iceland                               | MX | Mexico                                    | US | United States of America |
| CA | Canada                   | IT | Italy                                 | NE | Niger                                     | UZ | Uzbekistan               |
| CF | Central African Republic | JP | Japan                                 | NL | Netherlands                               | VN | Viet Nam                 |
| CG | Congo                    | KE | Kenya                                 | NO | Norway                                    | YU | Yugoslavia               |
| CH | Switzerland              | KG | Kyrgyzstan                            | NZ | New Zealand                               | ZW | Zimbabwe                 |
| CI | Côte d'Ivoire            | KP | Democratic People's Republic of Korea | PL | Poland                                    |    |                          |
| CM | Cameroon                 | KR | Republic of Korea                     | PT | Portugal                                  |    |                          |
| CN | China                    | KZ | Kazakhstan                            | RO | Romania                                   |    |                          |
| CU | Cuba                     | LC | Saint Lucia                           | RU | Russian Federation                        |    |                          |
| CZ | Czech Republic           | LI | Liechtenstein                         | SD | Sudan                                     |    |                          |
| DE | Germany                  | LK | Sri Lanka                             | SE | Sweden                                    |    |                          |
| DK | Denmark                  | LR | Liberia                               | SG | Singapore                                 |    |                          |
| EE | Estonia                  |    |                                       |    |   |    |                          |

**SUPERANTIGENS****TECHNICAL FIELD**

5 This invention relates to superantigens, and to their use, including in diagnosis and/or treatment of disease.

**BACKGROUND ART**

10 Bacterial superantigens are the most potent T cell mitogens known. They stimulate large numbers of T cells by directly binding to the side of the MHC class II and T cell Receptor (TcR) molecules. Because they override the normally exquisite MHC restriction phenomenon of T cell antigen recognition, they are prime candidates for either causing the onset of autoimmune diseases or exacerbating an existing 15 autoimmune disorder.

The applicants have identified genes coding for four novel superantigens from *S. pyogenes*. It is broadly to these superantigens and polynucleotides encoding them that the present invention is directed.

20

**SUMMARY OF THE INVENTION**

In one aspect the invention provides a superantigen selected from any one of SMEZ-2, SPE-G, SPE-H and SPE-J, or a functionally equivalent variant thereof.

25

In a further aspect the invention provides a polynucleotide molecule comprising a sequence encoding a superantigen chosen from SMEZ-2, SPE-G, SPE-H, SPE-J, or a functionally equivalent variant thereof.

30

In another aspect of the invention there is provided a method of subtyping *Streptococci* on the basis of superantigen genotype comprising detection of the presence of any or all of the above four superantigens or the corresponding polynucleotides.

In a further aspect the invention provides a construct comprising any of the above superantigens (or superantigen variants) bound to a cell-targeting molecule, which is preferably a tumour-specific antibody.

5 In yet a further aspect, the invention provides a pharmaceutical composition for therapy or prophylaxis comprising a superantigen or superantigen variant as described above linked to cell targeting molecule.

Other aspects of the invention will be apparent from the description provided below,  
10 and from the appended claims.

#### **DESCRIPTION OF DRAWINGS**

While the invention is broadly defined above, it further includes embodiments of  
15 which the following description provides examples. It will also be better understood with reference to the following drawings:

**Fig 1: Multiple alignment of superantigen protein sequences.**

20 The protein sequence of mature toxins were aligned using the PileUp programme on the GCG package. Regions of high sequence identity are in black boxes. The boxes below the sequences indicate the structural elements of SPE-C, as determined from the crystal structure (Roussel et al 1997 Nat. Struct. Biol. 4 no8:635-43). Regions with highest homology correspond to the  $\beta$ 4,  $\beta$ 5,  $\alpha$ 4 and  $\alpha$ 5 regions in SPE-C. The  
25 clear box near the C-terminus represents a primary zinc binding motif, a common feature of all toxins shown. The arrows on top of the sequence alignment show the regions of sequence diversity between SMEZ and SMEZ-2.

**Figure 2: The nucleotide sequence of the portion of the smez-2 gene (SEQ ID NO. 1)  
30 coding the mature SMEZ-2 superantigen (SEQ ID NO. 2).**

**Figure 3: The nucleotide sequence of the portion of the spe-g gene (SEQ ID NO. 3)  
coding the mature SPE-G superantigen (SEQ ID NO. 4).**

Figure 4: The nucleotide sequence of the portion of the spe-h gene (SEQ ID NO. 5) coding the mature SPE-H superantigen (SEQ ID NO. 6).

Figure 5: The nucleotide sequence of the portion of the spe-j gene (SEQ ID NO. 7) 5 coding part of the mature SPE-J superantigen (SEQ ID NO. 8).

Figure 6: Gel electrophoresis of the purified recombinant toxins.

A. Two micrograms of purified recombinant toxin were run on a 12.5% SDS-10 polyacrylamide gel to show the purity of the preparations; B. Two micrograms of purified recombinant toxin were run on an isoelectric focusing gel (5.5% PAA, pH 5-8). The isoelectric point (IEP) of rSMEZ-2, rSPE-G and rSPE-H is similar and was estimated at pH 7-8. The IEP of rSMEZ was estimated at pH 6-6.5.

15 Figure 7: Stimulation of human T cells with recombinant toxins.

PBLs were isolated from human blood samples and incubated with varying concentrations of recombinant toxin. After 3d, 0.1  $\mu$ Ci [ $^3$ H]-thymidine was added and cells were incubated for another 24h, before harvested and counted on a 20 gamma counter. O, unstimulated;  $\blacktriangle$ , rSMEZ;  $\checkmark$ , rSMEZ-2;  $\blacklozenge$ , rSPE-G;  $\blacksquare$ , rSPE-H.

Figure 8: Jurkat cell assay

Jurkat cells (bearing a V $\beta$ 8 TcR) and LG-2 cells were mixed with varying 25 concentrations of recombinant toxin and incubated for 24h, before SeI cells were added. After 1d, 0.1  $\mu$ Ci [ $^3$ H]-thymidine was added and cells were counted after another 24h. The V $\beta$ 8 targeting SEE was used as a positive control. The negative control was SEA. Both SMEZ and SMEZ-2 were potent stimulators of Jurkat cells, indicating their ability to specifically target V $\beta$ 8 bearing T cells. O, unstimulated; 30  $\blacktriangle$ , rSEA;  $\checkmark$ , rSEE;  $\blacklozenge$ , rSMEZ;  $\blacksquare$ , rSMEZ-2.

Figure 9: Zinc dependent binding of SMEZ-2 to LG-2 cells

LG-2 cells were incubated in duplicates with 1 ng of  $^{125}\text{I}$  labelled rSMEZ-2 and increasing amounts of unlabeled toxin at 37°C for 1h, and then the cells were washed and counted.

5 O, incubation in media;  $\blacktriangle$ , incubation in media plus 1mM EDTA;  $\checkmark$ , incubation in media plus 1 mM EDTA, 2 mM ZnCl<sub>2</sub>.

Figure 10: Scatchard analysis of SMEZ-2 binding to LG-2 cells

10 One nanogram  $^{125}\text{I}$ -labeled rSMEZ-2 was incubated in duplicates with LG-2 cells and a 2-fold dilution series of cold toxin (10  $\mu\text{g}$  to 10 pg). After 1h, cells were washed and counted. Scatchard plots were performed as described by Cunningham et al 1989 Science 243:1330-1336.

15 Figure 11: Summary of competitive binding experiments.

Efficiency of each labelled toxin to compete with a 10,000-fold molar excess of any other unlabeled toxin for binding to LG-2 cells.  $\square$ , no competition;  $\square$ , 25% competition;  $\blacksquare$ , 50% competition;  $\blacksquare$ , 75% competition;  $\blacksquare$ , 100% competition.

20 The results within the boxes are at the bottom right have previously been published (Li et al. 1997).

Figure 12: Competition binding study with SMEZ-2.

25 LG-2 cells were incubated in duplicates with 1 ng of  $^{125}\text{I}$ -labeled rSMEZ-2 and increasing amounts of unlabeled rSMEZ-2, rSEA, rSEB, rTSST or rSPE-C. After 1h cells were washed and counted.

O, rSMEZ-2;  $\blacktriangle$ , rSEA;  $\checkmark$ , rSEB;  $\blacksquare$ , rTSST;  $\blacklozenge$ , rSPE-C.

30 Figure 13: Southern blot analysis of genomic DNA with radiolabeled smez. HINDIII digested genomic DNA from various *Streptococcus* isolates was hybridized with a radiolabeled smez probe. Band A is a 1953 bp HindIII DNA fragment that carries the smez gene. Bands B and C are DNA fragments of about 4 kbp and 4.2 kbp, respectively, which both carry a smez like region. 1, *S. pyogenes* reference strain 35 (ATCC 700294, M1 type); 2, isolate 9639 (MNT); 3, isolate 11789 (MNT); 4, isolate

11152 (PT2612 type); 5, isolate RC4063 (group C streptococcus); 6, isolate 11070 (emm65 type); 7, DNA marker lane; 8, isolate 4202 (NZ5118/M92 type); 9, isolate 94/229 (M49 type); 10, isolate 11610 (emm57 type); 11, isolate 95/127 (NZ1437/M89 type); 12, isolate 94/330 (M4 type).

5

#### DESCRIPTION OF THE INVENTION

The focus of the invention is the identification of four superantigens (SPE-G, SPE-H, SPE-J and SMEZ-2) and the corresponding polynucleotides which encode them.

10

Figure 1 shows the amino acid sequences of the above four superantigens together with those of previously identified superantigens SMEZ, SPE-C and SEA.

15

Of the four superantigens SPE-G, SPE-H, SPE-J and SMEZ-2, the latter is perhaps of greatest interest.

20

The *smez-2* gene which encodes SMEZ-2 was identified in an experiment designed to produce recombinant SMEZ protein from *S. pyogenes* 2035 genomic DNA. A full length *smez* gene was isolated from the strain but the DNA sequence of the *smez* gene of strain 2035 showed nucleotide changes in 36 positions (or 5%) compared to *smez* from strain M1 (Fig. 1). The deduced protein sequences differed in 17 amino acid residues (or 8.1%). This difference establishes this as a new gene, *smez-2*, and the encoded protein as a new superantigen, SMEZ-2.

25

The most significant difference between SMEZ and SMEZ-2 is an exchanged pentapeptide sequence at position 96-100, where the EEPMS sequence of SMEZ is converted to KTSIL in SMEZ-2 (Fig. 1). A second difference is at position 111-112, where an RR dipeptide is exchanged for GK in SMEZ-2. The remaining 10 different residues are spread over almost the entire primary sequence.

30

Figure 2 shows the nucleotide sequence encoding mature SMEZ-2 and the deduced amino acid sequence.

Likewise, Figures 3 to 5 show the nucleotide sequence encoding mature SPE-G, SPE-H and SPE-J superantigens, respectively, together with their respective deduced amino acid sequences.

5 The invention is of course not restricted to superantigens/polynucleotides having the specific sequences of Figures 1 to 5. Instead, functionally equivalent variants are contemplated.

10 The phrase "functionally equivalent variants" recognises that it is possible to vary the amino acid/nucleotide sequence of a peptide while retaining substantially equivalent functionality. For example, a peptide can be considered a functional equivalent of another peptide for a specific function if the equivalent peptide is immunologically cross-reactive with and has at least substantially the same function as the original peptide. The equivalent can be, for example, a fragment of 15 the peptide, a fusion of the peptide with another peptide or carrier, or a fusion of a fragment which additional amino acids. For example, it is possible to substitute amino acids in a sequence with equivalent amino acids using conventional techniques. Groups of amino acids normally held to be equivalent are:

20 (a) Ala, Ser, Thr, Pro, Gly;  
(b) Asn, Asp, Glu, Gln;  
(c) His, Arg, Lys;  
(d) Met, Leu, Ile, Val; and  
(e) Phe, Tyr, Trp.

25

Equally, nucleotide sequences encoding a particular product can vary significantly simply due to the degeneracy of the nucleic acid code.

30 Variants can have a greater or lesser degree of homology as between the variant amino acid/nucleotide sequence and the original.

35 Polynucleotide or polypeptide sequences may be aligned, and percentage of identical nucleotides in a specified region may be determined against another sequence, using computer algorithms that are publicly available. Two exemplary algorithms for aligning and identifying the similarity of polynucleotide sequences are the

BLASTN and FASTA algorithms. The similarity of polypeptide sequences may be examined using the BLASTP algorithm. Both the BLASTN and BLASTP software are available on the NCBI anonymous FTP server (<ftp://ncbi.nlm.nih.gov>) under [/blast/executables/](#). The BLASTN algorithm version 2.0.4 [Feb-24-1998], set to the 5 default parameters described in the documentation of variants according to the present invention. The use of the BLAST family of algorithms, including BLASTN and BLASTP, is described at NCBI's website at URL <http://www.ncbi.nlm.nih.gov/BLAST/newblast.html> and in the publication of Altschul, Stephen F., *et al.* (1997), "Gapped BLAST and PSI-BLAST: a new 10 generation of protein database search programs", *Nucleic Acids Res.* 25:3389-34023. The computer algorithm FASTA is available on the Internet at the ftp site <ftp://ftp.virginia.edu/pub/fasta/>. Version 2.0u4, February 1996, set to the default 15 parameters described in the documentation and distributed with the algorithm, is also preferred for use in the determination of variants according to the present invention. The use of the FASTA algorithm is described in W. R. Pearson and D. J. Lipman, "Improved Tools for Biological Sequence Analysis", *Proc. Natl. Acad. Sci. USA* 85:2444-2448 (1988) and W. R. Pearson, "Rapid and Sensitive Sequence Comparison with FASTP and FASTA", *Methods in Enzymology* 183:63-98 (1990).

20 The following running parameters are preferred for determination of alignments and similarities using BLASTN that contribute to E values (as discussed below) and percentage identity: Unix running command: blastall -p blastn -d embldb -e 10 -G 1 -E 1 -r 2 -v 50 -b 50 -I queryseq -o results; and parameter default values:

-p Program Name [String]

25 -d Database [String]

-e Expectation value (E) [Real]

-G Cost to open a gap (zero invokes default behaviour) [Integer]

-E Cost to extend a gap (zero invokes default behaviour) [Integer]

-r Reward for a nucleotide match (blastn only) [Integer]

30 -v Number of one-line descriptions (V) [Integer]

-b Number of alignments to show (B) [Integer]

-i Query File [File In]

-o BLAST report Output File [File Out] Optional

For BLASTP the following running parameters are preferred: blastall -p blastp -d swissprotdb -e 10 -G 1 -E 1 -v 50 -b 50 -I queryseq -o results

-p Program Name [String]  
-d Database [String]  
-e Expectation value (E) [Real]  
-G Cost to open a gap (zero invokes default behaviour) [Integer]  
5 -E Cost to extend a gap (zero invokes default behaviour) [Integer]  
-v Number of one-line descriptions (v) [Integer]  
-b Number of alignments to show (b) [Integer]  
-i Query File [File In]  
-o BLAST report Output File [File Out] Optional

10

The "hits" to one or more database sequences by a queried sequence produced by BLASTN, BLASTP, FASTA, or a similar algorithm, align and identify similar portions of sequences. The hits are arranged in order of the degree of similarity and the length of sequence overlap. Hits to a database sequence generally represent an 15 overlap over only a fraction of the sequence length of the queried sequence.

The BLASTN and FASTA algorithms also produce "Expect" or E values for alignments. The E value indicates the number of hits one can "expect" to see over a certain number of contiguous sequences by chance when searching a database of a 20 certain size. The Expect value is used as a significance threshold for determining whether the hit to a database, such as the preferred EMBL database, indicates true similarity. For example, an E value of 0.1 assigned to a hit is interpreted as meaning that in a database of the size of the EMBL database, one might expect to see 0.1 matches over the aligned portion of the sequence with a similar score simply 25 by chance. By this criterion, the aligned and matched portions of the sequences then have a 90% probability of being the same. For sequences having an E value of 0.01 or less over aligned and matched portions, the probability of finding a match by chance in the EMBL database is 1% or less using the BLASTN or FASTA algorithm.

30 According to one embodiment, "variant" polynucleotides, with reference to each of the polynucleotides of the present invention, preferably comprise sequences having the same number or fewer nucleic acids than each of the polynucleotides of the present invention and producing an E value of 0.01 or less when compared to the polynucleotide of the present invention. That is, a variant polynucleotide is any 35 sequence that has at least a 99% probability of being the same as the

polynucleotide of the present invention, measured as having an E value of 0.01 or less using the BLASTN or FASTA algorithms set at the parameters discussed above.

Variant polynucleotide sequences will generally hybridize to the recited 5 polynucleotide sequence under stringent conditions. As used herein, "stringent conditions" refers to prewashing in a solution of 6X SSC, 0.2% SDS; hybridizing at 65°C, 6X SSC, 0.2% SDS overnight; followed by two washes of 30 minutes each in 1X SSC, 0.1% SDS at 65°C and two washes of 30 minutes each in 0.2X SSC, 0.1% SDS at 65°C.

10

The superantigens of the invention together with their fragments and other variants may be generated by synthetic or recombinant means. Synthetic polypeptides having fewer than about 100 amino acids, and generally fewer than about 50 amino acids, may be generated by techniques well known to those of ordinary skill in the 15 art. For example, such peptides may be synthesised using any of the commercially available solid-phase techniques such as the Merrifield solid phase synthesis method, where amino acids are sequentially added to a growing amino acid chain (see Merrifield, J. Am. Chem. Soc 85: 2146-2149 (1963)). Equipment for automatic synthesis of peptides is commercially available from suppliers such as Perkin 20 Elmer/Applied Biosystems, Inc. and may be operated according to the manufacturers instructions.

Each superantigen, or a fragment or variant thereof, may also be produced recombinantly by inserting a polynucleotide (usually DNA) sequence that encodes 25 the superantigen into an expression vector and expressing the superantigen in an appropriate host. Any of a variety of expression vectors known to those of ordinary skill in the art may be employed. Expression may be achieved in any appropriate host cell that has been transformed or transfected with an expression vector containing a DNA molecule which encodes the recombinant protein. Suitable host 30 cells include prokaryotes, yeasts and higher eukaryotic cells. Preferably, the host cells employed are *E. coli*, yeasts or a mammalian cell line such as COS or CHO, or an insect cell line, such as SF9, using a baculovirus expression vector. The DNA sequence expressed in this manner may encode the naturally occurring superantigen, fragments of the naturally occurring protein or variants thereof.

35

DNA sequences encoding the superantigen or fragments may be obtained, for example, by screening an appropriate *S. pyogenes* cDNA or genomic DNA library for DNA sequences that hybridise to degenerate oligonucleotides derived from partial amino acid sequences of the superantigen. Suitable degenerate oligonucleotides 5 may be designed and synthesised by standard techniques and the screen may be performed as described, for example, in Maniatis *et al.* *Molecular Cloning - A Laboratory Manual*, Cold Spring Harbour Laboratories, Cold Spring Harbour, NY (1989).

10 Identification of these superantigens and of their properties gives rise to a number of useful applications. A first such application is in the genotyping of organisms by reference to their superantigen profile.

An illustration of this is subtyping of strains of *S. pyogenes*.  
15 One feature which has been observed is that all clones of *S. pyogenes* so far found to be positive for SMEZ express either SMEZ-1 or SMEZ-2 but not both. Thus they are mutually exclusive, which enables a rapid diagnostic test which tells whether an isolate or a patient sample is either SMEZ-1 +ve or SMEZ-2 +ve. This will assist in 20 the typing of the isolate.

This general diagnostic approach is most simply achieved by providing a set of primers which amplify either all or a subset of superantigen genes and that generate gene specific fragments. This can be modified to provide a simple 25 qualitative ELISA-strip type kit that detects biotin labelled PCR fragments amplified by the specific primers and hybridised to immobilised sequence specific probes. This has usefulness for screening patient tissue samples for the presence of superantigen producing streptococcal strains.

30 Such approaches are well known and well understood by those persons skilled in the art.

Another approach is to provide monoclonal antibodies to detect each of the 35 streptococcal superantigens. An ELISA kit containing such antibodies would allow the screening of large numbers of streptococcal isolates. A kit such as this would be

useful for agencies testing for patterns in streptococcal disease or food poisoning outbreaks.

Another potential diagnostic application of the superantigens of the invention is in  
5 the diagnosis of disease, such as Kawasaki Syndrome (KS).

KS is an acute multi-system vasculitis of unknown aetiology. It occurs world-wide but is most prevalent in Japan or in Japanese ancestry. It primarily affects infants and the young up to the age of 16. It is an acute disease that without treatment, 10 can be fatal. Primary clinical manifestations include

- Prolonged fever
- Bilateral non-exudative conjunctivitis
- Induration and erythema of the extremities
- Inflammation of the lips and oropharynx
- 15 • Polymorphous skin rash
- Cervical lymphadenopathy
- In 15-25% of cases, coronary arterial lesions develop.

These indications are used as a primary diagnosis of KS.

20 In Japan and the US, KS has become one of the most common causes of acquired heart disease in children. Treatment involves the immediate intravenous administration of gamma globulin (IVGG) during the acute phase of the disease and this significantly reduces the level of coronary lesions.

25 There are two clear phases to the disease, an acute phase and a convalescent phase. The acute phase is marked by strong immune activation. Several reports have suggested that superantigens are involved and many attempts have been made to link the disease to infection with superantigen producing strains of 30 *Streptococcus pyogenes*. Features of the acute phase of KS are the expansion of V $\beta$  2 and to a lesser extent V $\beta$ 8 bearing T cells and an increase of DR expression T cells (a hallmark of T cell activation).

35 Because SMEZ-2 stimulates both V $\beta$ 2 and V $\beta$ 8 bearing T cells, testing for SMEZ-2 production is potentially very useful in the diagnosis of KS.

Antibodies to the superantigens for use in applications such as are described above are also provided by this invention. Such antibodies can be polyclonal but will preferably be monoclonal antibodies.

5

Monoclonal antibodies with affinities of  $10^{-8}$  M<sup>-1</sup> or preferably  $10^{-9}$  to  $10^{-10}$  M<sup>-1</sup> or stronger will typically be made by standard procedures as described, eg. in Harlow & Lane (1988) or Goding (1986). Briefly, appropriate animals will be selected and the desired immunization protocol followed. After the appropriate period of time, the 10 spleens of such animals are excised and individual spleen cells fused, typically, to immortalised myeloma cells under appropriate selection conditions. Thereafter, the cells are clonally separated and the supernatants of each clone tested for their production of an appropriate antibody specific for the desired region of the antigen.

15 Other suitable techniques for preparing antibodies well known in the art involve *in vitro* exposure of lymphocytes to the antigenic polypeptides, or alternatively, to selection of libraries of antibodies in phage or similar vectors.

Also, recombinant immunoglobulins may be produced using procedures known in 20 the art (see, for example, US Patent 4,816,567 and Hodgson J. (1991)).

The antibodies may be used with or without modification. Frequently, antibodies will be labeled by joining, either covalently or non-covalently, a substance which provides for a detectable signal. A wide variety of labels and conjugation techniques 25 are known and are reported extensively in the literature. Suitable labels include radionuclides, enzymes, substrates, cofactors, inhibitors, fluorescent agents, chemiluminescent agents, magnetic particles and the like. Patents teaching the use of such labels include US Patents 3,817,837; 3,850,752; 3,939,350; 3,996,345; 4,277,437; 4,275,149; and 4,366,241.

30

The immunological assay in which the antibodies are employed can involve any convenient format known in the art.

35 The nucleotide sequence information provided herein may be used to design probes and primers for probing or amplification of parts of the sme2, spe-g, spe-h and

spe-j genes. An oligonucleotide for use in probing or PCR may be about 30 or fewer nucleotides in length. Generally, specific primers are upwards of 14 nucleotides in length. For optimum specificity and cost effectiveness, primers of 16-24 nucleotides in length are preferred. Those skilled in the art are well versed in the design of 5 primers for use in processes such as PCR.

If required, probing can be done with entire polynucleotide sequences provided herein as SEQ ID NOS 1, 3, 5 and 7, optionally carrying revealing labels or reporter molecules.

10

Such probes and primers also form aspects of the present invention.

Probing may employ the standard Southern blotting technique. For instance, DNA may be extracted from cells and digested with different restriction enzymes. 15 Restriction fragments may then be separated by electrophoresis on an agarose gel, before denaturation and transfer to a nitrocellulose filter. Labelled probes may be hybridised to the DNA fragments on the filter and binding determined. DNA for probing may be prepared from RNA preparations from cells. Probing may optionally be done by means of so-called "nucleic acid chips" (see Marshall and Hodgson 20 (1998) *Nature Biotechnology* 16:27-31).

In addition to diagnostic applications, another application of the superantigens is reliant upon their ability to bind to other cells.

25 One of the most important features of superantigens is that they bind a large number of T cell receptor molecules by binding to the V $\beta$  domain. They are the most potent of all T cell mitogens and are therefore useful to recruit and activate T cells in a relatively non-specific fashion.

30 This ability enables the formation of constructs in which the superantigen (or at least the T-cell binding portion of it) is coupled to a cell-targeting molecule, particularly an antibody, more usually a monoclonal antibody.

When a monoclonal antibody that targets a specific cell surface antigen (such as a 35 tumor specific antigen) is coupled to a superantigen in such a construct, this generates a reagent that on the one hand will bind specifically to the tumor cell, and

on the other hand recruit and selectively active T cells for the purpose of killing the targeted cell.

Bi-specific constructs of this type have important applications in therapy  
5 particularly cancer therapy) and again may be prepared by means known to those skilled in art. For example SMEZ-2 may be coupled to a tumor specific monoclonal antibody. The constructs may be incorporated into conventional carriers for pharmaceutically-active proteins.

10 Various aspects of the invention will now be described with reference to the following experimental section, which is included for illustrative purposes.

**EXAMPLE**

15 **SECTION A: SUPERANTIGEN IDENTIFICATION AND CHARACTERISATION**

***Materials and Methods***

***Identification of novel SAGs***

20 The novel superantigens were identified by searching the *S. pyogenes* M1 genome database at the University of Oklahoma (<http://www.genome.ou.edu/strep.html>) with highly conserved  $\beta$ 5 and  $\alpha$ 4regions of streptococcal and staphylococcal superantigens, using a TBLastN search programme.

25 The open reading frames were defined by translating the DNA sequences around the matching regions and aligning the protein sequences to known superantigens using the computer programmes Gap. Multiple alignments and dendograms were performed with Lineup and Pileup. The FASTA programme was used for searching the SwissProt (Amos Bairoch, Switzerland) and PIR (Protein Identification Resource, 30 USA) protein databases.

The leader sequences of SPE-G and SPE-H were predicted using the SP Scan programme All computer programmes are part of the GCG package (version 8).

*Cloning of smeZ, smeZ-2, spe-g and spe-h.*

Fifty nanograms of *S.pyogenes* M1 (ATCC 700294) or *S.pyogenes* 2035 genomic DNA was used as a template to amplify the smeZ DNA fragment and the smeZ-2 DNA fragment, respectively, by PCR using the primers

5      smeZ-forward (TGGGATCCTTAGAAGTAGATAATA) and  
smeZ-reverse (AAGAATTCTAGGAGTCAATTTC) and Taq Polymerase (Promega). The  
primers contain a terminal tag with the restriction enzyme recognition sequences  
BamHI and EcoRI, respectively. The amplified DNA fragment, encoding the mature  
protein without the leader sequence (Kamezawa et al, 1997 Infect. Immun. 65  
10     no9:38281-33) was cloned into a T-tailed pBlueScript SKII vector (Stratagene).

Spe-g and spe-h were cloned in a similiar approach, using the primers spe-g-fw

(CTGGATCCGATGAAAATTAAAAGATTAA) and spe-g-rev

(AAGAATTCGGGGGGAGAATAG), and primers spe-h-fw

15     (TTGGATCCAATTCTTATAATACAACC) and spe-h-rev  
(AAAAGCTTTAGCTGATTGACAC), respectively.

The DNA sequences of the subcloned toxin genes were confirmed by the dideoxy  
chain termination method using a Licor automated DNA sequencer. As the DNA

20     sequences from the genomic database are all unedited raw data, 3 subclones of  
every cloning experiment were analyzed to ensure that no Taq polymerase related  
mutations were introduced.

*Expression and purification of rSMEZ, rSMEZ-2, rSPE-G and rSPE-H.*

25     Subcloned smeZ, smeZ-2 and spe-g fragments were cut from pBlueScript SKII  
vectors, using restriction enzymes BamHI and EcoRI (LifeTech), and cloned into  
pGEX-2T expression vectors (Pharmacia). Due to an internal EcoRI restriction site  
within the spe-H gene, the pBlueScript:spe-h subclone was digested with BamHI  
and HindIII and the spe-h fragment was cloned into a modified pGEX-2T vector that  
30     contains a HindIII 3'cloning site.

Recombinant SMEZ, rSMEZ-2 and rSPE-H were expressed in *E.coli* DH5 $\alpha$  cells as  
glutathione-S-transferase (GST) fusion proteins. Cultures were grown at 37° C and  
induced for 3-4 h after adding 0.2 mM isopropyl- $\beta$ -D-thiogalactopyranoside (IPTG).

35     GST - SPE-G fusion protein was expressed in cells grown at 28° C.

The GST fusion proteins were purified on glutathione agarose as described previously (Li et al, 1997) and the mature toxins were cleaved off from GST by trypsin digestion. All recombinant toxins, except rSMEZ, were further purified by 5 two rounds of cation exchange chromatography using carboxy methyl sepharose (Pharmacia). The GST-SMEZ fusion protein was trypsin digested on the GSH-column and the flow through containing the SMEZ was collected.

*Gel electrophoresis*

10 All purified recombinant toxins were tested on a 12% SDS-polyacrylamide gel according the procedure of Laemmli. The isoelectric point of the recombinant toxins was determined by isoelectric focusing on a 5.5% polyacrylamide gel using ampholine pH 5-8 (Pharmacia Biotech). The gel was run for 90 min at 1 W constant power.

15

*Toxin proliferation assay*

Human peripheral blood lymphocytes (PBL) were purified from blood of a healthy donor by Histopaque Ficoll (Sigma) fractionation. The PBL were incubated in 96-well round bottom microtiter plates at  $10^5$  cells per well with RPMI-10 (RPMI with 10% 20 fetal calf serum) containing varying dilutions of recombinant toxins. The dilution series was performed in 1:5 steps from a starting concentration of 10 ng/ml of toxin. Pipette tips were changed after each dilution step. After 3 days 0.1  $\mu$ Ci [<sup>3</sup>H]thymidine was added to each well and cells were incubated for another 24 h. Cells were harvested and counted on a scintillation counter.

25

Mouse leukocytes were obtained from spleens of 5 different mouse strains (SJL, B10.M, B10/J, C3H and BALB/C). Splenocytes were washed in DMEM-10, counted in 5% acetic acid and incubated on microtiter plates at  $10^5$  cells per well with DMEM-10 and toxins as described for human PBLs.

30 TcR V $\beta$  analysis.

V $\beta$  enrichment analysis was performed by anchored multiprimer amplification (Hudson et al, 1993, J exp Med 177:175-185). Human PBLs were incubated with 20 pg/ml of recombinant toxin at  $10^6$  cells/ml for 3 d. A two-fold volume expansion of 35 the culture followed with medium containing 20 ng/ml IL-2. After another 24h,

stimulated and resting cells were harvested and RNA was prepared using Trizol reagent (Life Tech). A 500 bp  $\beta$ -chain DNA probe was obtained by anchored multiprimer PCR as described previously (38), radiolabeled and hybridized to del (36) individual V $\beta$ s and a C $\beta$  DNA region dot blotted on a Nylon membrane. The 5 membrane was analysed on a Molecular Dynamics Storm Phosphor imager using ImageQuant software. Individual V $\beta$ s were expressed as a percentage of all the V $\beta$ s determined by hybridization to the C $\beta$  probe.

*Jurkat cell assay*

10 Jurkat cells (a human T cell line) and LG-2 cells (a human B lymphoblastoid cell line, homozygous for HLA-DR1) were harvested in log phase and resuspended in RPMI-10. One hundred microliter of the cell suspension, containing  $1 \times 10^5$  Jurkat cells and  $2 \times 10^4$  LG-2 cells were mixed with 100  $\mu$ l of varying dilutions of recombinant toxins on 96 well plates. After incubating overnight at 37° C, 100  $\mu$ l 15 aliquots were transferred onto a fresh plate and 100  $\mu$ l ( $1 \times 10^4$ ) of SeI cells (IL-2 dependent murine T cell line) per well were added. After incubating for 24 h, 0.1  $\mu$ Ci [ $^3$ H]thymidine was added to each well and cells were incubated for another 24 h. Cells were harvested and counted on a scintillation counter. As a control, a dilution series of IL-2 was incubated with SeI cells.

20

*Computer aided modelling of protein structures*

Protein structures of SMEZ-2, SPE-G and SPE-H were created on a Silicon Graphics computer using InsightII/Homology software. The superantigens SEA, SEB and SPE-C were used as reference proteins to determine structurally conserved regions 25 (SCRs). Coordinate files for SEA (1ESF), for SEB (1SEB) and for SPE-C (1AN8) were downloaded from the Brookhaven Protein Database. The primary amino acid sequences of the reference proteins and SMEZ-2, SPE-G and SPE-H, respectively, were aligned and coordinates from superimposed SCR's were assigned to the model proteins. The loop regions between the SCRs were generated by random choice. 30 MolScript software (PJ Kraulis, 1991, J App Cratallography 24:946-50) was used for displaying the computer generated images.

*Radiolabeling and LG-2 binding experiments*

Recombinant toxin was radioiodinated by the chloramine T method as previously 35 described (by Li et al. 1997). Labeled toxin was seperated from free iodine by size

exclusion chromatography using Sephadex G25 (Pharmacia). LG2 cells were used for cell binding experiments, as described (Li et al. 1997). Briefly, cells were harvested, resuspended in RPMI-10 and mixed at  $10^6$  cells/ml with  $^{125}\text{I}$ -tracer toxin (1 ng) and 0.0001 to 10  $\mu\text{g}$  of unlabeled toxin and incubated at 37° C for 1 h. After 5 washing with ice cold RPMI-1 the pelleted cells were analyzed in a gamma counter. For zinc binding assays the toxins were incubated in either RPMI-10 alone, in RPMI-10 with 1 mM EDTA or in RPMI-10 with 1mM EDTA, 2 mM  $\text{ZnCl}_2$ .

Scatchard analysis was performed as described by Cunningham et al. (1989). For 10 competitive binding studies, 1 ng of  $^{125}\text{I}$ -tracer toxin (rSMEZ, rSMES-2, rSPE-G, rSPE-H, rSEA, rSPE-C, or rTSST) was incubated with 0.0001 to 10  $\mu\text{g}$  of unlabeled toxin (rSMEZ, rSMES-2, rSPE-G, rSPE-H, rSEA, rSEB, rSPE-C, and rTSST) for 1h. For SEB inhibition studies, 20 ng of  $^{125}\text{I}$ -rSEB was used as tracer and samples were 15 incubated for 4h.

15

### Results

#### *Identification and sequence analysis of superantigens.*

The Oklahoma University *Streptococcus pyogenes* M1 genome database is accessible 20 via the internet and contains a collection of more than 300 DNA sequence contigs derived from a shot gun plasmid library of the complete *S. pyogenes* M1 genome. The currently available DNA sequences cover about 95% of the total genome. This database was searched with a highly conserved superantigen peptide sequence, using a search program that screens the DNA database for peptide sequences in all 25 6 possible reading frames. 8 significant matches and predicted the open reading frames (ORFs) were found by aligning translated DNA sequences to complete protein sequences of known SAGs.

Five matches gave complete ORFs with significant homology to streptococcal and 30 staphylococcal superantigens. Three of these ORFs correlate to SPE-C, SSA and the recently described SMEZ (Kamezawa et al. 1997), respectively. The remaining two ORFs could not be correlated to any known protein in the SwissProt and PIR databases. These novel putative superantigen genes were named spe-g and spe-h (see Figs 3 and 4). One ORF could not be generated completely due to its location 35 close to the end of a contig. The DNA sequence of the missing 5'-end is located on

another contig, and individual contigs have yet to be assembled in the database. However, the available sequence shows an ORF for the 137 COOH-terminal amino acid residues of a putative novel superantigen which could not be found in the existing protein databases. This gene was named spe-j (see Fig. 5).

5

In two cases a complete ORF could not be defined due to several out-of-frame mutations. Although DNA sequencing errors on the unedited DNA sequences cannot be completely ruled out, the high frequency of inserts and deletions probably represent natural mutation events on pseudogenes, which are no longer used.

10

To produce recombinant proteins of SMEZ, SPE-G and SPE-H, individual genes (coding for the mature toxins without leader sequence) were amplified by PCR, and subcloned for DNA sequencing. Both, *Str. pyogenes* M1 and *Str. pyogenes* 2035 genomic DNA were used and individual toxin gene sequences compared between the 15 two strains. The spe-h gene was isolated from M1 strain, but could not be amplified from strain 2035 genomic DNA suggesting a restricted strain specificity for this toxin. The spe-g gene was cloned from both M1 and 2035, and DNA sequence analysis of both genes showed no differences. The full length smeZ gene was isolated from both strains, but DNA sequence comparison revealed some striking 20 differences. The smeZ gene of strain 2035 showed nucleotide changes in 36 positions (or 5%) compared to smeZ from strain M1 (Fig. 1). The deduced protein sequences differed in 17 amino acid residues (or 8.1%). This difference was sufficient to indicate a new gene. This gene was named smeZ-2, because it is 95% homologous to smeZ (see Fig. 2).

25

The most significant difference between SMEZ and SMEZ-2 is an exchanged pentapeptide sequence at position 96-100, where the EEPMS sequence of SMEZ is converted to KTSIL in SMEZ-2 (Fig. 1). A second cluster is at position 111-112, where an RR dipeptide is exchanged for GK in SMEZ-2. The remaining 10 different 30 residues are spread over almost the entire primary sequence.

A revised superantigen family tree, based on primary amino acid sequence homology now shows 3 general subfamilies; group A comprises SPE-C, SPE-J, SPE-G, SMEZ and SMEZ-2, group B comprises SEC1-3, SEB, SSA, SPE-A and SEG and

group C comprises SEA, SEE, SED, SEH and SEI. Two superantigens, TSST and SPE-H do not belong to any one of those subfamilies.

SMEZ, SMEZ-2, SPE-G and SPE-J are most closely related to SPE-C, increasing the 5 number of this subfamily from 2 to 5 members. SPE-G shows the highest protein sequence homology with SPE-C (38.4% identity and 46.6% similarity). The homology of SPE-J to SPE-C is even more significant (56% identity and 62% similarity), but this comparison is only preliminary due to the missing NH<sub>2</sub>-terminal sequence. SMEZ shows 30.9% / 40.7% homology to SPE-C and SMEZ-2 is 92% / 10 93% homologous to SMEZ.

SPE-H builds a new branch in the family tree and is most closely related to SED, showing 25% identity and 37.3% similarity.

15 Multiple alignment of SAg protein sequences (Fig. 1) shows that similarities are clustered within structure determining regions, represented by  $\alpha$ 4,  $\alpha$ 5,  $\beta$ 4 and  $\beta$ 5 regions. This applies to all toxins of the superantigen family (data not shown) and explains why superantigens like SPE-C and SEA have very similar overall structures despite their rather low sequence identity of 24.4 %.

20 Although SPE-H is less related to SPE-C it shows 2 common features with the "SPE-C subfamily": (I) a truncated NH<sub>2</sub>-terminus, lacking the  $\alpha$ 1 region and (II) a primary zinc binding motif (H-X-D) at the C-terminus (Fig. 1). It has been shown for several superantigens that this motif is involved in a zinc coordinated binding to the  $\beta$ -chain 25 of HLA-DR1.

Fusion proteins of GST-SMEZ, GST-SMEZ-2 and GST-SPE-H were completely 30 soluble and gave yields of about 30 mg per liter. The GST-SPE-G fusion was insoluble when grown at 37° C, but mostly soluble when expressed in cells growing at 28° C. Although soluble GST-SPE-G yields were 20-30 mg per liter, solubility decreased after cleavage of the fusion protein with trypsin. Soluble rSPE-G was achieved by diluting the GST-SPE-G to less than 0.2 mg/ml prior to cleavage. After cation exchange chromatography, purified rSPE-G could be stored at about 0.4 mg/ml.

Recombinant SMEZ could not be separated from GST by ion exchange chromatography. Isoelectric focusing revealed that the isoelectric points of the two proteins are too similar to allow separation (data not shown). Therefore, rSMEZ was released from GST by cleaving with trypsin while still bound to the GSH agarose 5 column. Recombinant SMEZ was collected with the flow through.

The purified recombinant toxins were applied to SDS-PAGE and isoelectric focusing (Fig. 6). Each toxin ran as a single band on the SDS PAA gel confirming their purity and their calculated molecular weights of 24.33 (SMEZ), 24.15 (SMEZ-2), 24.63 10 (SPE-G) and 23.63 (SPE-H) (Fig. 6A). The isoelectric focusing gel (Fig. 6B) shows a significant difference between rSMEZ and rSMEZ-2. Like most other staphylococcal and streptococcal toxins, rSMEZ-2 possesses a slightly basic isoelectric point at pH 7-8, but rSMEZ is acidic with an IEP at pH 6-6.5.

15 *T cell proliferation and V $\beta$  specificity*

To ensure the native conformation of the purified recombinant toxins, a standard [ $^3$ H]thymidine incorporation assay was performed to test for their potency to stimulate peripheral blood lymphocytes (PBLs). All toxins were active on human T cells (Fig. 7). Recombinant SEA, rSEB, rSPE-C and rTSST were included as 20 reference proteins. The mitogenic potency of these toxins was lower than described previously, but is regarded as a more accurate figure. In previous studies, a higher starting concentration of toxin (100 ng/ml) was used and tips were not changed in between dilutions. This led to significant carryover across the whole dilution range. On this occasion, the starting concentration was 10 ng/ml and tips were changed in 25 between dilutions preventing any carryover.

The half maximal response for rSPE-G and rSPE-H was 2 pg/ml and 50 pg/ml, respectively. No activity was detected at less than 0.02 pg/ml and 0.1 pg/ml, respectively. Both toxins are therefore less potent than rSPE-C. Recombinant SMEZ 30 was similar in potency to rSPE-C, with a  $P_{50\%}$  value of 0.08 pg/ml and no detectable proliferation at less than 0.5 fg/ml. Recombinant SMEZ-2 showed the strongest mitogenic potency of all toxins tested or, as far as can be determined, described elsewhere. The  $P_{50\%}$  value was determined at 0.02 pg/ml and rSMEZ-2 was still active at less than 0.1 pg/ml. All  $P_{50\%}$  values are summarized in Table 1.

TABLE 1

## POTENCY OF RECOMBINANT TOXINS ON HUMAN AND MOUSE T CELLS.

| TOXIN  | PROLIFERATION POTENTIAL $P_{50\%}$ [pg/ml] |          |          |          |          |          |
|--------|--|----------|----------|----------|----------|----------|
|        | HUMAN                                      | SJL      | B10.M    | B10/J    | C3H      | BALB/C   |
| SEA    | 0.1  | 20       | 12       | 1.8      | 19       | 1000     |
| SEE    | 0.2  | 10       | 12       | 1.5      | 50       | 15       |
| SEB    | 0.8  | 7000     | 80,000   | 5000     | 10,000   | 1000     |
| TSST   | 0.2  | 20       | 1000     | 1.2      | 100      | 10       |
| SPE-C  | 0.1  | >100,000 | >100,000 | >100,000 | >100,000 | >100,000 |
| SMEZ   | 0.08                                       | 80       | 80       | 100      | 9000     | 200      |
| SMEZ-2 | 0.02                                       | 100      | 15       | 10       | 800      | 18       |
| SPE-G  | 2  | >100,000 | >100,000 | >100,000 | >100,000 | >100,000 |
| SPE-H  | 50   | 15       | 800      | 5000     | 100      | 1000     |

Human PBLs and mouse T cells were stimulated with varying amounts of recombinant toxin. The  $P_{50\%}$  value reflects the concentration of recombinant toxin required to induce 50% maximal cell proliferation. No proliferation was detected for rSPE-C and rSPE-G at any concentration tested on murine T cells.

Murine T cells from 5 different mouse strains were tested for their mitogenic response to rSMEZ, rSMEZ-2, rSPE-G and rSPE-H (Table 1). Recombinant SPE-G showed no activity against any of the mouse strains tested. Recombinant SPE-H, rSMEZ and rSMEZ-2 showed varied potency depending on the individual mouse 5 strain. For example, rSMEZ-2 was 500-fold more potent than rSPE-H in the B10/J strain, while rSPE-H was 7.5-fold more active than rSMEZ-2 in the SJL strain.

The most consistently potent toxin on murine T cells was rSMEZ-2 with  $P_{50\%}$  values of 10 pg/ml in B10/J and 800 pg/ml in C3H. Recombinant SMEZ varied between 80 10 pg/ml in SJL and B10.M and 9000 pg/ml in C3H. The  $P_{50\%}$  value for rSPE-H was between 15 pg/ml in SJL and 5000 pg/ml in B10/J.

TABLE 2

V $\beta$  SPECIFICITY OF RECOMBINANT TOXINS ON HUMAN PBLS.

| V $\beta$ | PERCENT V $\beta$ ENRICHMENT |             |             |             |             |
|-----------|------------------------------|-------------|-------------|-------------|-------------|
|           | Resting                      | SMEZ        | SMEZ-2      | SPE-G       | SPE-H       |
| 1.1       | 0.2                          | 0.3         | 0.4         | 1.2         | 1           |
| 2.1       | 0.4                          | <u>8.4</u>  | 1           | <u>17.9</u> | <u>8.6</u>  |
| 3.2       | 4.8                          | 3.1         | 2.5         | 3           | 2.4         |
| 4.1       | 3.5                          | <u>24.8</u> | <u>14.4</u> | <u>11.2</u> | 5.2         |
| 5.1       | 6.2                          | 1.4         | 2.5         | 5.7         | 2.2         |
| 5.3       | 5.6                          | 2.2         | 4.1         | 4.7         | 4.1         |
| 6.3       | 3                            | 0.8         | 2.3         | 4.7         | 3.5         |
| 6.4       | 5.4                          | 2.1         | 5.9         | 9.6         | 5.6         |
| 6.9       | 6.9                          | 3.5         | 9.3         | <u>19.1</u> | 12.2        |
| 7.3       | 3.5                          | <u>15.3</u> | 7.3         | 3.2         | <u>12.6</u> |
| 7.4       | 9                            | 13.5        | 11.7        | 2.9         | 6.3         |
| 8.1       | 8.7                          | <u>20.7</u> | <u>36</u>   | 4.5         | 2.4         |
| 9.1       | 0.3                          | 0.05        | 0           | <u>1.2</u>  | <u>2.3</u>  |
| 12.3      | 0.8                          | 1.6         | 2           | <u>3.2</u>  | 2.6         |
| 12.5      | 3                            | 1.2         | 2           | 3           | 2.3         |
| 15.1      | 0.6                          | 0.5         | 0.7         | 1.2         | 0.8         |
| 23.1      | 0.2                          | 0.1         | 0.3         | 0.8         | <u>1</u>    |
| total     | 62.1                         | 99.7        | 102.8       | 97.1        | 75.2        |

Human PBLS were incubated with 20 pg/ml of recombinant toxin for 4d. Relative enrichment of V $\beta$  cDNAs was analyzed from RNA of stimulated and resting PBLS by anchored primer PCR and reverse dot blot to a panel of 17 different V $\beta$  cDNAs.

The values representing the highest V $\beta$  enrichment are underlined.

The human TcR V $\beta$  specificity of the recombinant toxins was determined by multiprimer anchored PCR and dot blot analysis using a panel of 17 human V $\beta$  DNA regions. The V $\beta$  enrichment after stimulation with toxin was compared to the V $\beta$  profile of unstimulated PBLs (Table 2). The sum total of all V $\beta$ s stimulated by 5 rSMEZ, rSMEZ-2 and rSPE-G was close to 100 % suggesting that the V $\beta$ s used in the panel represent all the targeted V $\beta$ s. On the other hand, the total of the V $\beta$ s stimulated by rSPE-H was only 75%. It is therefore likely that rSPE-H also stimulated some less common V $\beta$ s, which are not represented in the panel. The most dramatic response was seen with all toxins, except rSMEZ2, on V $\beta$ 2.1 bearing 10 T cells (21-fold for rSMEZ, 45-fold for rSPE-G and 22-fold for rSPE-H). In contrast, rSMEZ2 gave only a 2.5-fold increase of V $\beta$ 2.1 T-cells. SPE-G also targeted V $\beta$ 4.1, V $\beta$ 6.9, V $\beta$ 9.1 and V $\beta$ 12.3 (3-4 fold). A moderate enrichment of V $\beta$ 12.6, V $\beta$ 9.1 and V $\beta$ 23.1 (4-8 fold) was observed with rSPE-H. Both, rSMEZ and rSMEZ2, targeted 15 V $\beta$ 4.1 and V $\beta$ 8.1 with similar efficiency (3-7-fold). This finding is of particular interest, because V $\beta$ 8.1 activity had been found in some, but not all *Str. pyogenes* culture supernatants and in crude preparations of SPE-A and SPE-C. Moreover, SPE-B has often been claimed to have V $\beta$ 8 specific activity, but has since been shown to be a contaminant previously called SpeX. The ability of rSMEZ and rSMEZ-2 to stimulate the V $\beta$ 8.1 Jurkat cell line was tested (Fig. 8) Recombinant 20 SMEZ was less potent than the control toxin (rSEE), showing a half maximal response of 0.2 ng/ml, compared to 0.08 ng/ml with rSEE, but rSMEZ-2 was more potent than rSEE (0.02 ng/ml). No proliferation activity was observed with the negative control toxin rSEA.

25 *MHC class II binding*

To determine if there were significant structural differences, the protein structures of SMEZ-2, SPE-G and SPE-H were modelled onto the superimposed structurally conserved regions of SEA, SEB and SPE-C. The models showed that in all three 30 proteins, the 2 amino acid side chains of the COOH-terminal primary zinc binding motif are in close proximity to a third potential zinc ligand to build a zinc binding site, similar to the zinc binding site observed in SEA and SPE-C.

The zinc binding residues in SPE-C are H167, H201, D203, and it is thought that H81 from the HLA-DR1  $\beta$ -chain binds to the same zinc cation to form a regular 35 tetrahedral complex. The two ligands of the primary zinc binding motif, H201 and

D203, are located on the  $\beta$ 12 strand, which is part of the  $\beta$ -grasp motif, a common structural domain of superantigens. The third ligand, H167, comes from the  $\beta$ 10 strand (Roussel et al. 1997).

5 In the model of SPE-G three potential zinc binding ligands (H167, H202 and D204) are located at corresponding positions. In the SMEZ-2 and the SPE-H models, the two corresponding  $\beta$ 12 residues are H202, D204 and H198, D200, respectively. The third ligand in SPE-H (D160) and in SMEZ-2 (H162) comes from the  $\beta$ 9 strand and is most similar to H187 in SEA. It has been shown from crystal structures that H167  
10 of SPE-C and H187 of SEA are spatially and geometrically equivalent sites (Scad et al. 1997, *Embo J* 14 no 14:3292-301; Roussel et al. 1997).

All superantigens examined so far, except SPE-C, bind to a conserved motif in the MHC class II  $\alpha$ 1-domain. In SEB and TSST, hydrophobic residues on the loop  
15 between the  $\beta$ 1 and  $\beta$ 2 strand project into a hydrophobic depression in the MHCII  $\alpha$ 1-domain. This loop region has changed its character in SPE-C, where the hydrophobic residues (F44, L45, Y46 and F47 in SEB) are substituted by the less hydrophobic residues T33, T34 and H35. A comparison of this region on the computer generated models revealed that the generic HLA-DR1  $\alpha$ -chain binding site  
20 might also be missing. As the loop regions are generated by random choice, no conclusions can be drawn from their conformation in the models. However, in none of the three models does the  $\beta$ 1- $\beta$ 2-loop have the required hydrophobic features observed in SEB and TSST Swaminathan, S. et al., *Nature* 359, No. 6398:801-6 (1992), Acharya et al., *Nature* 367, No. 6458: 94-7 (1994). The residues are I25, D26,  
25 F27, K28, T29 and S30 in SMEZ-2, T31, T32, N33, S34 in SPE-G and K28, N29, S30, P31, D32, I33, V34 and T35 in SPE-H.

SMEZ-2 differs from SMEZ in only 17 amino acids. In the model of SMEZ-2 with the position of those 17 residues, most of the exchanges are located on loop regions,  
30 most significantly on the  $\beta$ 5- $\beta$ 6 loop with 5 consecutive residues replaced. The potential zinc binding site and the  $\beta$ 1- $\beta$ 2 loop are not affected by the replaced amino acids.

The TcR V $\beta$  specificity differs between SMEZ and SMEZ-2 by one V $\beta$ . SMEZ strongly  
35 stimulates V $\beta$ 2 T cells, but SMEZ-2 does not (Table 2). One or more of the 17

exchanged residues in SMEZ/SMEZ-2 may therefore be directly involved in TcR binding. The exact position of the TcR binding site can not be predicted from the model as several regions have been implicated in TcR binding for different toxins. Crystal structures of SEC2 and SEC3, complexed with a TcR  $\beta$ -chain indicated the 5 direct role of several residues located on  $\alpha$ 2, the  $\beta$ 2- $\beta$ 3 loop, the  $\beta$ 4- $\beta$ 5 loop and  $\alpha$ 4 (Fields et al. 1996 *Nature* 384 no 6605:188-92). On the other hand, binding of TSST to the TcR involves residues from  $\alpha$ 4, the  $\beta$ 7- $\beta$ 8 loop and the  $\alpha$ 4- $\beta$ 9 loop (Acharya et al. 1994, *Nature* 367 no 6548:94-7). The SMEZ-2 model shows 3 residues, which may contribute to TcR binding. In SMEZ, Lys is exchanged for Glu at position 80 10 and Thr is exchanged for Ile at position 84, both on the  $\beta$ 4- $\beta$ 5 loop. On the COOH-terminal end of the  $\alpha$ 4 helix, Ala is replaced by Ser at position 143.

The results from the computer modelled protein structures suggest that all 4 toxins, SMEZ, SMEZ-2, SPE-G and SPE-H, might bind to the HLA-DR1  $\beta$ -chain in a zinc 15 dependent fashion, similar to SEA and SPE-C, but might not be able to interact with the HLA-DR1  $\alpha$ -site, a situation that has so far only been observed with SPE-C (Roussel et al. 1997; Li et al. 1997).

To find out whether or not zinc is required for binding of the toxins to MHC class II, 20 a binding assay was performed using human LG-2 cells (which are MHC class II expressing cells homozygous for HLA-DR1). Direct binding of  $^{125}$ I-labeled toxins was completely abolished in the presence of 1 mM EDTA (Fig. 9, Table 3). When 2 mM ZnCl<sub>2</sub> was added, binding to the LG-2 cells could be restored completely. These 25 results show that the toxins bind in a zinc dependent mode, most likely to the HLA-DR1  $\beta$ -chain similar to SEA and SPE-C. However, it does yet not exclude the possibility of an additional binding to the HLA-DR1  $\alpha$ -chain.

TABLE 3

**BINDING AFFINITIES AND ZINC DEPENDENCIES FOR SUPERANTIGENS TO  
HUMAN CLASS II**

| TOXIN  | MHC CLASS II BINDING<br>kd [nM] | ZINC DEPENDENCY |
|--------|---------------------------------|-----------------|
|        |                                 | ++              |
| SEA    | 36/1000                         | ++              |
| SEB    | 340                             | -               |
| TSST   | 130                             | -               |
| SPE-C  | 70                              | ++              |
| SMEZ   | 65/1000                         | ++              |
| SMEZ-2 | 25/1000                         | ++              |
| SPE-G  | 16/1000                         | ++              |
| SPE-H  | 37/2000                         | ++              |

The binding affinities of the toxins to MHC class II were determined by Scatchard analysis using LG-2 cells. Zinc dependency was determined by binding of recombinant toxins to LG-2 cells in the presence and absence of 5 EDTA, as described in the Materials and Methods section.

The biphasic binding of SEA to HLA-DR1 can be deduced from Scatchard analysis. It shows that SEA possesses a high affinity binding site of 36 nM (which is the zinc dependent  $\beta$ -chain binding site) and a low affinity binding site of 1  $\mu$ M ( $\alpha$ -chain binding site). On the other hand, only one binding site for HLA-DR1 was deduced from Scatchard analysis with SEB, TSST and SPE-C, respectively (Table 3).

Therefore, Scatchard analysis was performed with radiolabeled rSMEZ, rSMEZ-2, rSPE-G and rSPE-H using LG-2 cells. All four toxins showed multiphasic curves 15 with at least 2 binding sites on LG-2 cells, a high affinity site of 15-65 nM and a low affinity site of 1-2  $\mu$ M (Fig. 10, Table 3).

In a further attempt to determine the orientation of the toxins on MHC class II competition binding experiments were performed. The recombinant toxins and reference toxins (rSEA, rSEB, rSPE-C and rTSST) were radiolabeled and tested with 5 excess of unlabeled toxin for binding to LG-2 cells. The results are summarized in Fig. 11. Both, rSEA and rSPE-C, inhibited binding of labeled rSMEZ, rSMEZ-2, rSPE-G and rSPE-H, respectively. However, rSPE-C only partially inhibited binding (50%) of the labeled rSMEZ-2 (Fig. 12). Recombinant SEB did not compete with any other toxin, even at the highest concentration tested. Recombinant TSST was only 10 slightly competitive against <sup>125</sup>I-labeled rSMEZ, rSMEZ-2 and rSPE-G, respectively, and did not inhibit rSPE-H binding at all.

Reciprocal competition experiments were performed. Recombinant SMEZ, rSMEZ-2 and rSPE-H prevented <sup>125</sup>I-rSEA from binding to LG-2 cells. However, only partial 15 competition (50%) was observed even at the highest toxin concentrations (10,000 fold molar excess). Recombinant SPE-G did not prevent binding of <sup>125</sup>I-rSEA and <sup>125</sup>I-rTSST binding was only partially inhibited by rSMEZ, rSMEZ-2 and rSPE-H, but not by rSPE-G. Significantly, none of the toxins inhibited <sup>125</sup>I-rSEB binding, even at the highest concentration tested.

20 In a further set of competition binding experiments, rSMEZ, rSMEZ-2, rSPE-G and rSPE-H were tested for competition against each other. Both, rSMEZ and rSMEZ-2 competed equally with each other and also prevented binding of labeled rSPE-G and rSPE-H. In contrast, rSPE-G and rSPE-H did not inhibit any other toxin binding 25 suggesting that these toxins had the most restricted subset of MHC class II molecules, which represent specific receptors.

## SECTION B: GENOTYPING

### 30 *Genotyping of S. pyogenes isolates*

Purified genomic DNA from all *Str. Pyogenes* isolates was used for PCR with specific primers for the smeZ, spe-g and spe-h genes as described above and by Proft (1999). In addition, a primer pair specific to a DNA region encoding the 23S rRNA, oligo 23rRNA forward (GCTATTTCGGAGAGAACCAG) and oligo 23rRNA reverse 35 (CTGAAACATCTAAGTAGCTG) was designed and used for PCR as a positive control.

*Southern blot analysis*

About 5 $\mu$ g of genomic DNA was digested using restriction enzyme HindIII (GIBCO) and loaded onto a 0.7% agarose gel. The DNA was transferred from the gel to a 5 Hybond-N+ nylon membrane (Amersham) as described by Maniatis (1989). A 640 bp DNA fragment of the *smez-2* gene was radiolabeled using the RadPrime Labeling System (GIBCO) and  $\alpha$  <sup>32</sup>P-dCTP (NEN). The nylon blots were hybridized with the radiolabeled probe in 2x SSC, 0.5% SDS, 5x Denhards overnight at 65°C. After washing twice in 0.2x SSC, 0.1% SDS at 65°C the blots were analysed on a Storm 10 PhosphorImager.

**RESULTS**

PCR based genotyping was performed in order to determine the frequency of the 15 genes *smez*, *spe-g* and *spe-h* in streptococcal isolates (Table 4). The PCR primers for *smez* were designed to anneal with both genes, *semz* and *smez-2*. 103 isolates were collected between 1976 and 1998 from varying sites in patients with varying infections, although the majority were from sore throats. They comprised 94 group 20 *A Streptococcus* (GAS) and 9 non-GAS, which were *S. agalactiae* (group B), *S. equis* (group C) and *Streptococcus spp* (group C). There are 25 distinct Memm types represented among the GAS isolates, 13 isolates are M non-typable (MNT) and in 2 cases the M type is unknown. The analysis was undertaken blinded to the details of each isolate and 2 duplicate isolates were included (95/31 and 4202) to demonstrate the reproducibility of the testing procedure. The isolates are listed in 2 25 groups. Group 1 contained isolates collected within a large time frame (1976 to 1996). Group 2 comprised of isolates collected within a short time (1998).

All of the 9 non-GAS isolates (belonging to groups B, C and G) were negative for the 30 tested sag genes. The frequencies for *smez*, *spe-g* and *spe-h* within the GAS isolates were 95.6%, 100% and 23.9% respectively. A correlation between a certain Memm type and the presence of the *spe-h* gene could not be established. The deficiency in this current set was that only 5M/memm types were represented by more than one isolate. The most frequent serotype was M/memm 12 with 13 isolates, from which 7 were positive and 6 were negative for *spe-h* suggesting genetic diversity within the

M/emm12 strain. In contrast, all 12 tested NZ1437/M89 isolates were negative for spe-h.

The high frequencies of smez and spe-g is of particular interest as this has not been  
5 described for any other streptococcal sag gene thus far. Other spe genes, like speA,  
speC and ssa are found at much lower frequencies and horizontal gene transfer  
might explain the varying frequencies of these genes in different strains. In  
contrast, both smez and spe-g were found in virtually all tested GAS isolates. Only  
10 4 GAS isolates (11152, 11070, 94/229 and 11610) tested negative for smez. These  
were PT2612, emm65, M49 and emm57. Southern hybridisation was performed to  
find out if the negative PCR results were due to lack of the smez gene or to  
lack/alteration of the primer binding site(s). HindIII digested genomic DNA of  
selected streptococcal isolates was probed with a 640 bp radiolabeled smz-2 PCR  
fragment (Fig. 13). The smez gene is located on a 1953 bp HindIII fragment of about  
15 4kb (fragment B), but not to the SMEZ bearing fragment A (lanes 4, 6, 9, 10). In  
addition, the smez probe bound to a second DNA fragment of about 4.2 kb (fragment  
C) in isolate 11152 (lane 4). In the M1 reference strain (lane 1) and in isolate 4202  
(lane 8) the smez probe also bound to fragment B, in addition to fragment A.  
Fragment B in the M1 strain contains a 180 bp region that shares 97% sequence  
20 homology with the 3' end of the smez gene. These results suggest that the 4 PCR  
negative isolates possess a truncated smez gene or a smez-like sequence, but not a  
complete smez gene.

Table 4

| Group 1: Isolates collected between 1976 and 1996 |       |          |      |            |         |       |       |      |     |
|---|-------|----------|------|------------|---------|-------|-------|------|-----|
| Strain No.  | Group | M/emm    | Site | Disease    | Rib.DNA | Spe-g | Spe-h | Smez | Vβ8 |
| FP 1943   | A     | M53      | ts   | ST         | +       | +     | -     | +    | -   |
| FP 2658   | A     | M59      | ts   | ST         | +       | +     | -     | +    | -   |
| FP 4223   | A     | M80      | ts   | ST         | +       | +     | -     | +    | +   |
| FP 5417   | A     | M41      | ts   | ST         | +       | +     | -     | +    | +   |
| FP 5847   | A     | M1       | ts   | ST         | +       | +     | -     | +    | +   |
| FP 5971   | A     | M57      | ts   | ST         | +       | +     | +     | +    | -   |
| 1/5045  | A     | M4       | ts   | ST         | +       | +     | -     | +    | +   |
| 79/1575   | A     | M1       | ts   | Tcarriage  | +       | +     | +     | +    | +   |
| 81/3033   | A     | M12      | ts   | ST         | +       | +     | +     | +    | +   |
| 82/20   | A     | M4       | sk   | ulcer      | +       | +     | -     | +    | +   |
| 82/532  | A     | M12      | ts   | ST         | +       | +     | +     | +    | +   |
| 82/675  | A     | NZ1437 § | ws   | wound      | +       | +     | -     | +    | +   |
| 84/141  | A     | M12      | ts   | ST         | +       | +     | +     | +    | +   |
| 84/1733   | A     | M4       | ts   | ST         | +       | +     | -     | +    | +   |
| 84/781  | A     | NZ1437 § | ts   | ST         | +       | +     | -     | +    | +   |
| 85/1  | A     | M12      | ts   | ST         | +       | +     | -     | +    | +   |
| 85/167  | A     | M12      | ts   | ST         | +       | +     | +     | +    | +   |
| 85/314  | A     | NZ1437 § | ws   | wound      | +       | +     | -     | +    | +   |
| 85/437  | A     | M81      | ws   | inf eczema | +       | +     | -     | +    | +   |
| 85/722  | A     | n.d.     | ?    | ?          | +       | +     | -     | +    | -   |
| 86/435  | A     | M4       | ts   | RF         | +       | +     | -     | +    | +   |
| 87/169  | A     | M12      | ts   | ST         | +       | +     | +     | +    | +   |
| 87/19   | A     | M12      | ts   | ST         | +       | +     | +     | +    | +   |
| 87/781  | A     | M12      | ts   | ST         | +       | +     | -     | +    | +   |
| 88/627  | A     | M12      | sk   | wound      | +       | +     | -     | +    | -   |
| 89/22   | A     | M12      | ts   | fever      | +       | +     | -     | +    | +   |
| 89/25   | A     | M12      | ur   | erysipelas | +       | +     | +     | +    | +   |
| 89/26   | A     | M1       | ts   | AGN        | +       | +     | -     | +    | +   |
| 89/54   | A     | NZ1437 § | ts   | ST         | +       | +     | -     | +    | +   |
| 90/306  | A     | M5       | ear  | otorrhoea  | +       | +     | -     | +    | +   |
| 90/424  | A     | M4       | ts   | ST         | +       | +     | -     | +    | +   |
| 91/542  | A     | M12      | ts   | ST         | +       | +     | -     | +    | +   |
| 94/11   | A     | NZ1437 § | ps   | abscess    | +       | +     | -     | +    | +   |
| 94/229  | A     | M49      | hvs  | endometr.  | +       | +     | +     | -    | -   |
| 94/330  | A     | M4       | ts   | SF         | +       | +     | -     | +    | +   |
| 94/354  | A     | M12      | ts   | ST         | +       | +     | -     | +    | +   |
| 94/384  | A     | M4       | sk   | wound      | +       | +     | -     | +    | +   |
| 94/712  | A     | NZ1437 § | ws   | cellulitis | +       | +     | -     | +    | +   |
| 95/127  | A     | NZ1437 § | bc   | cellulitis | +       | +     | -     | +    | +   |

|          |   |          |     |            |   |   |   |   |   |
|----------|---|----------|-----|------------|---|---|---|---|---|
| 95/31    | A | NZ1437 § | ws  | abscess    | + | + | - | + | + |
| 95/31(2) | A | NZ1437 § | ws  | abscess    | + | + | - | + | + |
| 95/361   | A | NZ1437 § | ps  | abscess    | + | + | - | + | + |
| 96/1     | A | n.d.     | ?   | ?          | + | + | - | + | + |
| 96/364   | A | NZ1437 § | bc  | burns      | + | + | - | + | + |
| 96/551   | A | M4       | eye | eye infect | + | + | - | + | + |
| 96/610   | A | M4       | ts  | SF         | + | + | - | + | + |
| D21      | A | M1       | ts  | Tcarriage  | + | + | - | + | + |
|          |   |          |     |            |   |   |   |   |   |
| RC4063   | C | -        | ts  | ST         | + | - | - | - | - |
| SP9205   | C | -        | ts  | ST         | + | - | - | - | - |
| NI6174   | G | -        | ts  | ST         | + | - | - | - | - |
| NI6192   | B | -        | ts  | ST         | + | - | - | - | - |
| VC4141   | G | -        | ts  | ST         | + | - | - | - | - |

## Group 2: Isolates collected in 1998

| Strain No. | student ID | group | M/emm    | site | disease | rib.DNA | spe-g | spe-h | smez | Vβ8  |
|------------|------------|-------|----------|------|---------|---------|-------|-------|------|------|
| 4202 *     | 3310       | A     | NZ5118II | ts   | ST      | +       | +     | -     | +    | +    |
| 4202(2)    | 3310       | A     | NZ5118II | ts   | ST      | +       | +     | -     | +    | +    |
| 9606       | 2252       | A     | MNT      | ts   | ST      | +       | +     | -     | +    | -    |
| 9639       | 2184       | A     | MNT      | ts   | ST      | +       | +     | +     | +    | +    |
| 9779       | 3230       | A     | cmm56    | ts   | ST      | +       | +     | -     | +    | +    |
| 9893       | 6144       | A     | PT180    | ts   | ST      | +       | +     | +     | +    | +    |
| 9894       | 6564       | A     | emm59    | ts   | ST      | +       | +     | -     | +    | +    |
| 10019      | 6264       | A     | emm44    | ts   | ST      | +       | +     | +     | +    | -    |
| 10028      | 9366       | A     | emm41    | ts   | ST      | +       | +     | -     | +    | +    |
| 10134      | 1880       | A     | ST4547   | ts   | ST      | +       | +     | -     | +    | -    |
| 10303      | 3564       | A     | emm59    | ts   | ST      | +       | +     | -     | +    | -    |
| 10307      | 4850       | A     | NZ5118II | ts   | ST      | +       | +     | -     | +    | +    |
| 10438      | 4904       | A     | ST3018   | ts   | ST      | +       | +     | -     | +    | +    |
| 10463      | TSP        | A     | cmm49    | ts   | ST      | +       | +     | -     | +    | -    |
| 10649      | 11510      | A     | ST2267   | ts   | ST      | +       | +     | -     | +    | +    |
| 10730      | 11503      | A     | MNT      | ts   | ST      | +       | +     | -     | +    | -    |
| 10742      | 3374       | A     | ST809    | ts   | ST      | +       | +     | -     | +    | +    |
| 10761      | 3254       | A     | MNT      | ts   | ST      | +       | +     | -     | +    | -    |
| 10763      | 6614       | PT    | 3875     | ts   | ST      | +       | +     | -     | +    | 1078 |
|            |            |       |          |      |         |         |       |       |      | 2    |
| 4850       | A          | MNT   | ts       | ST   | +       | +       | +     | +     | +    | +    |
| 10791      | 10290      | A     | MNT      | ts   | ST      | +       | +     | +     | +    | +    |
| 10792      | 10308      | A     | MNT      | ts   | ST      | +       | +     | +     | +    | -    |
| 10846      | 8854       | A     | NZ1437 § | ts   | ST      | +       | +     | -     | +    | +    |

|        |       |   |          |    |    |   |   |   |   |   |
|--------|-------|---|----------|----|----|---|---|---|---|---|
| 10902  | 6264  | A | NZ5118II | ts | ST | + | + | - | + | + |
| 10989  | 5194  | A | PT2841   | ts | ST | + | + | - | + | - |
| 11070  | 1434  | A | emm65    | ts | ST | + | + | + | - | - |
| 11072  | 1880  | A | ST4547   | ts | ST | + | + | - | + | - |
| 11083  | 4538  | A | MNT      | ts | ST | + | + | - | + | - |
| 11093  | 9791  | A | MNT      | ts | ST | + | + | + | + | + |
| 11152  | 2030  | A | PT2612   | ts | ST | + | + | + | - | - |
| 11222  | 4928  | A | NZ5118II | ts | ST | + | + | + | + | + |
| 11227  | 8854  | A | emm14    | ts | ST | + | + | - | + | - |
| 11244  | 2252  | A | ST4547   | ts | ST | + | + | - | + | - |
| 11276  | 4524  | A | MNT      | ts | ST | + | + | - | + | - |
| 11299  | 2950  | A | emm80    | ts | ST | + | + | - | + | + |
| 11574  | 3186  | A | ST809    | ts | ST | + | + | - | + | + |
| 11580  | 3280  | A | emm53    | ts | ST | + | + | - | + | - |
| 11610  | 2424  | A | emm57    | ts | ST | + | + | + | - | - |
| 11646  | 1880  | A | ST4547   | ts | ST | + | + | - | + | - |
| 11681  | 3564  | A | emm12    | ts | ST | + | + | - | + | + |
| 11686  | 5528  | A | PT5757   | ts | ST | + | + | - | + | + |
| 11745  | 12397 | A | emm59    | ts | ST | + | + | - | + | - |
| 11789  | 1568  | A | MNT      | ts | ST | + | + | - | + | - |
| 11802  | 3266  | A | MNT      | ts | ST | + | + | - | + | - |
| 11869  | 2950  | A | ST4547   | ts | ST | + | + | - | + | - |
| 11961  | 4916  | A | MNT      | ts | ST | + | + | - | + | - |
| 12015  | 12373 | A | emm59    | ts | ST | + | + | + | + | - |
|        |       |   |          |    |    |   |   |   |   |   |
| 7625   | 8215  | B | -        | ts | ST | + | - | - | - | - |
| 8011   | 3238  | B | -        | ts | ST | + | - | - | - | - |
| 10388  | 1653  | G | -        | ts | ST | + | - | - | - | - |
| O12633 | 5395  | B | -        | ts | ST | + | - | - | - | - |

**Table 4:** Genotyping of streptococcal isolates. The isolates were collected between 1976 and 1996 (group 1) and in 1998 (group 2) from patients with varying diseases. The results are based on PCR analysis using purified genomic DNA and specific primers for each of the sag genes.

The non Gas are: B, *S. agalactiae*; C, *S. equis*; G, *Streptococcus spp.*  
 MNT, M non typable: ts, throat site; ws, wound site; sk, skin; ps, pus site; hvs, high vaginal site; bc, blood culture; ST, sore throat; SF, scarlet fever; RF, rheumatic fever; AGN, acute glomerulonephritis; T carriage, throat carriage.

\* and †, duplicate isolates; §, recently assigned as M89; ††, recently assigned as M92.

### **INDUSTRIAL APPLICATION**

5

The superantigens of the invention, polynucleotides which encode them and antibodies which bind them have numerous applications. A number of these are discussed above (including *Streptococci* subtyping, diagnostic applications and therapeutic applications) but it will be appreciated that these are but examples.

10 Other applications will present themselves to those skilled in the art and are in no way excluded from the scope of the invention.

It will also be appreciated that the foregoing examples are illustrations of the invention. The invention may be carried out with the numerous variations and 15 modifications as will be apparent to those skilled in the art. For example, a native superantigen may be replaced by a synthetic superantigen with one or more deletions, insertions and/or substitutions relative to the corresponding natural superantigen, provided that the superantigen activity is retained. Likewise there are many variations in the way in which the invention can be used in other aspects 20 of it.

### **REFERENCES**

25 Marrack, P., and J. Kappler. 1990. The staphylococcal enterotoxins and their relatives. *Science* 248:705-711.

Huber, B.T., P.N. Hsu, and N. Sutkowski. 1996. Virus-encoded superantigens. *Microbiol. Rev.* 60, no. 3:473-82.

30 Alouf, J.E., H. Knoell, and W. Koehler. 1991. The family of mitogenic, shock-inducing and superantigenic toxins from staphylococci and streptococci. *Sourcebook of bacterial protein toxins.*, eds. J.E. Alouf and J.H. Freer. Academic Press, San Diego. 367-414 pp.

Betley, M.J., D.W. Borst, and L.B. Regassa. 1992. Staphylococcal enterotoxins, toxic shock syndrome toxin and streptococcal exotoxins: a comparative study of their molecular biology. *Chem. Immunol.* 55:1-35.

5 Ren, K., J.D. Bannan, V. Pancholi, A.L. Cheung, J.C. Robbins, V.A. Fischetti, and J.B. Zabriskie. 1994. Characterization and biological properties of a new staphylococcal exotoxin. *J. Exp. Med.* 180, no. 5:1675-83.

10 Munson, S.H., M.T. Tremaine, M.J. Betley, and R.A. Welch. 1998. Identification and Characterization Of Staphylococcal Enterotoxin Types G and I From *Staphylococcus Aureus*. *Infect. Immun.* 66, no. 7:3337-3348.

15 Herman, A., J.W. Kappler, P. Marrack, and A.M. Pullen. 1991. Superantigens: mechanism of T-cell stimulation and role in immune responses. *Annu. Rev. Immunol.* 9:745-772.

20 Janeway, C.J., J. Yagi, P.J. Conrad, M.E. Katz, B. Jones, S. Vroegop, and S. Buxser. 1989. T-cell responses to Mls and to bacterial proteins that mimic its behavior. *Immunol. Rev.* 107:61-68.

25 Kotzin, B.L., D.Y. Leung, J. Kappler, and P. Marrack. 1993. Superantigens and their potential role in human disease. *Adv. Immunol.* 54, no. 99:99-166.

30 Bohach, G.A., D.J. Fast, R.D. Nelson, and P.M. Schlievert. 1990. Staphylococcal and streptococcal pyrogenic toxins involved in toxic shock syndrome and related illnesses. *Crit. Rev. Microbiol.* 17, no. 4:251-72.

Weeks, C.R., and J.J. Ferretti. 1986. Nucleotide Sequence of the Type A Streptococcal Exotoxin (Erythrogenic Toxin) Gene from *Streptococcus pyogenes* Bacteriophage T12. *Infect. Immun.* 52:144-150.

Goshorn, S.C., G.A. Bohach, and P.M. Schlievert. 1988. Cloning and characterization of the gene, speC, for pyrogenic exotoxin type C from *Streptococcus pyogenes*. *Mol. Gen. Genet.* 212, no. 1:66-70.

5 Mollick, J.A., G.G. Miller, J.M. Musser, R.G. Cook, D. Grossman, and R.R. Rich. 1993. A novel superantigen isolated from pathogenic strains of *Streptococcus pyogenes* with aminoterminal homology to staphylococcal enterotoxins B and C. *J. Clin. Invest.* 92, no. 2:710-9.

10 Van Den Busche, R.A., J.D. Lyon, and G.A. Bohach. 1993. Molecular evolution of the staphylococcal and streptococcal pyrogenic toxin gene family. *Mol. Phylogenet. Evol.* 2:281-292.

Dellabona, P., J. Peccoud, J. Kappler, P. Marrack, C. Benoist, and D. Mathis. 1990.

15 Superantigens interact with MHC class II molecules outside of the antigen groove. *Cell* 62, no. 6:1115-21.

Fraser, J.D. 1989. High-affinity binding of staphylococcal enterotoxins A and B to HLA-DR. *Nature* 339, no. 6221:221-3.

20 Fleischer, B., and H. Schrezenmeier. 1988. T cell stimulation by staphylococcal enterotoxins. Clonally variable response and requirement for major histocompatibility complex class II molecules on accessory or target cells. *J. Exp. Med.* 167, no. 5:1697-707.

25 Mollick, J.A., R.G. Cook, and R.R. Rich. 1989. Class II MHC molecules are specific receptors for *staphylococcus enterotoxin A*. *Science* 244, no. 4906:817-20.

Schad, E.M., I. Zaitseva, V.N. Zaitsev, M. Dohlsten, T. Kalland, P.M. Schlievert, D.H.

30 Ohlendorf, and L.A. Svensson. 1995. Crystal structure of the superantigen staphylococcal enterotoxin type A. *EMBO J.* 14, no. 14:3292-301.

Swaminathan, S., W. Furey, J. Pletcher, and M. Sax. 1992. Crystal structure of staphylococcal enterotoxin B, a superantigen. *Nature* 359, no. 6398:801-6.

Papageorgiou, A.C., K.R. Acharya, R. Shapiro, E.F. Passalacqua, R.D. Brehm, and H.S. Tranter. 1995. Crystal structure of the superantigen enterotoxin C2 from *Staphylococcus aureus* reveals a zinc-binding site. *Structure* 3, no. 8:769-79.

5 Sundstrom, M., L. Abrahmsen, P. Antonsson, K. Mehindate, W. Mourad, and M. Dohlsten. 1996. The crystal structure of staphylococcal enterotoxin type D reveals Zn<sup>2+</sup>-mediated homodimerization. *EMBO J.* 15, no. 24:6832-40.

Acharya, K.R., E.F. Passalacqua, E.Y. Jones, K. Harlos, D.I. Stuart, R.D. Brehm, and H.S. Tranter. 1994. Structural basis of superantigen action inferred from crystal structure of toxic-shock syndrome toxin-1. *Nature* 367, no. 6458:94-7.

10 Roussel, A., B.F. Anderson, H.M. Baker, J.D. Fraser, and E.N. Baker. 1997. Crystal structure of the streptococcal superantigen SPE-C: dimerization and zinc binding suggest a novel mode of interaction with MHC class II molecules. *Nat. Struct. Biol.* 4, no. 8:635-43.

15 Kim, J., R.G. Urban, J.L. Strominger, and D.C. Wiley. 1994. Toxic shock syndrome toxin-1 complexed with a class II major histocompatibility molecule HLA-DR1. *Science* 266, no. 5192:1870-4.

20 Hurley, J.M., R. Shimonkevitz, A. Hanagan, K. Enney, E. Boen, S. Malmstrom, B.L. Kotzin, and M. Matsumura. 1995. Identification of class II major histocompatibility complex and T cell receptor binding sites in the superantigen toxic shock syndrome toxin 1. *J. Exp. Med.* 181, no. 6:2229-35.

25 Seth, A., L.J. Stern, T.H. Ottenhoff, I. Engel, M.J. Owen, J.R. Lamb, R.D. Klausner, and D.C. Wiley. 1994. Binary and ternary complexes between T-cell receptor, class II MHC and superantigen in vitro. *Source (Bibliographic Citation): Nature* 369, no. 6478:324-7.

30 Li, P.L., R.E. Tiedemann, S.L. Moffat, and J.D. Fraser. 1997. The superantigen streptococcal pyrogenic exotoxin C (SPE-C) exhibits a novel mode of action. *J. Exp. Med.* 186, no. 3:375-83.

Hudson, K.R., R.E. Tiedemann, R.G. Urban, S.C. Lowe, J.L. Strominger, and J.D. Fraser. 1995. Staphylococcal enterotoxin A has two cooperative binding sites on major histocompatibility complex class II. *J. Exp. Med.* 182, no. 3:711-20.

5 Kozono, H., D. Parker, J. White, P. Marrack, and J. Kappler. 1995. Multiple binding sites for bacterial superantigens on soluble class II MHC molecules. *Immunity* 3, no. 2:187-96.

10 Tiedemann, R.E., and J.D. Fraser. 1996. Cross-linking of MHC class II molecules by staphylococcal enterotoxin A is essential for antigen-presenting cell and T cell activation. *J. Immunol.* 157, no. 9:3958-66.

15 Braun, M.A., D. Gerlach, U.F. Hartwig, J.H. Ozegowski, F. Romagne, S. Carrel, W. Kohler, and B. Fleischer. 1993. Stimulation of human T cells by streptococcal "superantigen" erythrogenic toxins (scarlet fever toxins). *J. Immunol.* 150, no. 6:2457-66.

20 Kline, J.B., and C.M. Collins. 1997. Analysis of the interaction between the bacterial superantigen streptococcal pyrogenic exotoxin A (SpeA) and the human T-cell receptor. *Mol. Microbiol.* 24, no. 1:191-202.

25 Fleischer, B., A. Necker, C. Leget, B. Malissen, and F. Romagne. 1996. Reactivity of mouse T-cell hybridomas expressing human Vbeta gene segments with staphylococcal and streptococcal superantigens. *Infect. Immun.* 64, no. 3:987-94.

30 Toyosaki, T., T. Yoshioka, Y. Tsuruta, T. Yutsudo, M. Iwasaki, and R. Suzuki. 1996. Definition of the mitogenic factor (MF) as a novel streptococcal superantigen that is different from streptococcal pyrogenic exotoxins A, B, and C. *Eur. J. Immunol.* 26, no. 11:2693-701.

35 Kamezawa, Y., T. Nakahara, S. Nakano, Y. Abe, J. Nozaki-Renard, and T. Isono. 1997. Streptococcal mitogenic exotoxin Z, a novel acidic superantigenic toxin produced by a T1 strain of *Streptococcus pyogenes*. *Infect. Immun.* 65, no. 9:3828-33.

Hudson, K.R., H. Robinson, and J.D. Fraser. 1993. Two adjacent residues in Staphylococcal enterotoxins A and E determine Tcell receptor V beta specificity. *J. Exp. Med.* 177:175-185.

5 Kraulis, P.J. 1991. MOLSCRIPT": a program to produce both detailed and schematic plots of protein structures. *J. Appl. Crystallography* 24:946-950.

Cunningham, B.C., P. Jhurani, P. Ng, and J.A. Wells. 1989. Receptor and Antibody epitopes in human growth hormone identified by homologue scanning mutagenesis.

10 10 *Science* 243:1330-1336.

Fields, B.A., E.L. Malchiodi, H. Li, X. Ysern, C.V. Stauffacher, P.M. Schlievert, K. Karjalainen, and R.A. Mariuzza. 1996. Crystal structure of a T-cell receptor beta-chain complexed with a superantigen [see comments]. *Nature* 384, no. 6605:188-92.

15 Wen, R., G.A. Cole, S. Surman, M.A. Blackman, and D.L. Woodland. 1996. Major histocompatibility complex class II-associated peptides control the presentation of bacterial superantigens to T cells. *J. Exp. Med.* 183, no. 3:1083-92.

20 Thibodeau, J., I. Cloutier, P.M. Lavoie, N. Labrecque, W. Mourad, T. Jardetzky, and R.P. Sekaly. 1994. Subsets of HLA-DR1 molecules defined by SEB and TSST-1 binding. *Science* 266, no. 5192:1874-8.

Abe, J., B.L. Kotzin, K. Jujo, M.E. Melish, M.P. Glode, T. Kohsaka, and D.Y. Leung.

25 25 1992. Selective expansion of T cells expressing T-cell receptor variable regions V beta 2 and V beta 8 in Kawasaki disease. *PNAS* 89, no. 9:4066-70.

Kawasaki, T. 1967. Acute febrile mucocutaneous syndrome with lymphoid involvement with specific desquamation of the fingers and toes in children. *Jpn. J. Allergol.* 16:178.

30 Leung, D.Y., R.C. Giorno, L.V. Kazemi, P.A. Flynn, and J.B. Busse. 1995. Evidence for superantigen involvement in cardiovascular injury due to Kawasaki syndrome. *J. Immunol.* 155, no. 10:5018-21.

Cockerill, F.R., R.L. Thompson, J.M. Musser, P.M. Schlievert, J. Talbot, K.E. Holley, W.S. Harmsen, D.M. Ilstrup, P.C. Kohner, M.H. Kim, B. Frankfort, J.M. Manahan, J.M. Steckelberg, F. Roberson, and W.R. Wilson. 1998. Molecular, Serological, and Clinical Features Of 16 Consecutive Cases Of Invasive Streptococcal Disease. *Clin. Infect. Dis.* 26, no. 6:1448-1458.

Kapur, V., K.B. Reda, L.L. Li, L.J. Ho, R.R. Rich, and J.M. Musser. 1994. Characterization and distribution of insertion sequence IS1239 in *Streptococcus pyogenes*. *Gene* 150, no. 1:135-40.

10 T. Proft, S.L. Moffatt, C.J. Berkahn, and J.D. Fraser (1999). Identification and characterisation of novel superantigens from *Streptococcus pyogenes*. *Journal of Experimental Medicine* 189, No. 1:89-102.

15 T. Maniatis, E.F. Fritsch, and J. Sambrook. (1989). Molecular cloning: a laboratory manual. Cold Spring Harbour Laboratory, Cold Spring Harbour, NY, USA.

B.A. Roe, S.P. Linn, L. Song, X. Yuan, S. Clifton, M. McShan and J. Ferretti, (1999). *Str. Pyogenes* M1 genome sequencing project at Oklahoma University. Web:

20 <http://www.genome.ou.edu>.

**CLAIMS**

1. A superantigen selected from any one of SMEZ-2, SPE-G, SPE-H and SPE-J, or a functionally equivalent variant thereof.
- 5 2. A superantigen which is SMEZ-2 and which has an amino acid sequence of SEQ ID NO. 2, or a functionally equivalent variant thereof.
- 10 3. A superantigen which is SPE-G and which has an amino acid sequence of SEQ ID NO. 4, or a functionally equivalent variant thereof.
4. A superantigen which is SPE-H and which has an amino acid sequence of SEQ ID NO. 6, or a functionally equivalent variant thereof.
- 15 5. A superantigen which is SPE-J and which has an amino acid sequence which includes SEQ ID NO. 8, or a functionally equivalent variant thereof.
6. A polynucleotide comprising a nucleotide sequence encoding SMEZ-2 or a variant thereof as claimed in claim 2.
- 20 7. A polynucleotide according to claim 6 in which said nucleotide sequence is or includes SEQ ID NO. 1.
8. A polynucleotide comprising a nucleotide sequence encoding SPE-G or a variant thereof as claimed in claim 3.
- 25 9. A polynucleotide according to claim 8 in which said nucleotide sequence is or includes SEQ ID NO. 3.
- 30 10. A polynucleotide comprising a nucleotide sequence encoding SPE-H or a variant thereof as claimed in claim 4.
11. A polynucleotide according to claim 10 in which said nucleotide sequence is or includes SEQ ID NO 5.

12. A polynucleotide comprising a nucleotide sequence encoding SPE-J or a variant thereof as claimed in claim 5.
13. A polynucleotide according to claim 12 in which said nucleotide sequence includes SEQ ID NO. 7.
14. A method of subtyping *Streptococci* which includes the step of detecting the presence or absence of a superantigen as claimed in any one of claims 2 to 5.
- 10 15. A method of subtyping *Streptococci* which includes the step of detecting the presence or absence of a polynucleotide as claimed in any one of claims 6 to 13.
16. A construct which comprises a superantigen or variant thereof as claimed in any one of claims 2 to 5 and a cell-targeting molecule.
- 15 17. A construct according to claim 15 in which said cell-targeting molecule specifically binds a tumour cell.
18. A construct according to claim 15 or claim 16 in which said cell-targeting molecule is an antibody.
- 20 19. A pharmaceutical composition which includes a construct as claimed in any one of claims 15 to 17.
- 25 20. An antibody which binds superantigen SMEZ-2 as claimed in claim 2.
21. An antibody which binds superantigen SPE-G as claimed in claim 3.
22. An antibody which binds superantigen SPE-H as claimed in claim 4.
- 30 23. An antibody which binds superantigen SPE-J as claimed in claim 5.
24. A kit which includes an antibody as claimed in any one of claims 19 to 22.
- 35 25. A nucleic acid molecule which hybridises to a polynucleotide of claim 7.

26. A nucleic acid molecule which hybridises to a polynucleotide of claim 9.
27. A nucleic acid molecule which hybridises to a polynucleotide of claim 11.  
5
28. A nucleic acid molecule which hybridises to a polynucleotide of claim 13.
29. A kit which includes a nucleic acid molecule as claimed in any one of claims  
25 to 28.  
10
30. A method of diagnosing a disease which is caused or mediated by  
expression of a superantigen as claimed in claim 1 which includes the step of  
detecting the presence of said superantigen using an antibody as claimed in any  
one of claims 19 to 22, or detecting the presence of a polynucleotide encoding said  
15 superantigen using a nucleic acid molecule as claimed in any one of claims 25 to  
28.

## SEQUENCE LISTING

<110> Auckland UniServices Limited

<120> Superantigens

<130> 25426 MRB

<140>

<141>

<150> NZ 333589

<151> 1998-12-24

<160> 8

<170> PatentIn Ver. 2.1

<210> 1

<211> 702

<212> DNA

<213> *Streptococcus pyogenes*

<220>

<221> CDS

<222> (1)..(699)

<400> 1

atg aaa aaa aca aaa ctt att ttt tct ttt act tca ata ttc att gca 48  
Met Lys Lys Thr Lys Leu Ile Phe Ser Phe Thr Ser Ile Phe Ile Ala  
1 5 10 15

ata att tct cgt cct gtg ttt gga tta gaa gta gat aat aat tcc ctt 96  
Ile Ile Ser Arg Pro Val Phe Gly Leu Glu Val Asp Asn Asn Ser Leu  
20 25 30

cta agg aat atc tat agt acg att gta tat gaa tat tca gat ata gta 144  
Leu Arg Asn Ile Tyr Ser Thr Ile Val Tyr Glu Tyr Ser Asp Ile Val  
35 40 45

att gat ttt aaa acc agt cat aac tta gtg act aag aaa ctt gat gtt 192  
Ile Asp Phe Lys Thr Ser His Asn Leu Val Thr Lys Lys Leu Asp Val  
50 55 60

aga gat gct aga gat ttc ttt att aac tcc gaa atg gac gaa tat gca 240  
Arg Asp Ala Arg Asp Phe Phe Ile Asn Ser Glu Met Asp Glu Tyr Ala  
65 70 75 80

gcc aat gat ttt aaa act gga gat aaa ata gct gtg ttc tcc gtc cca 288  
 Ala Asn Asp Phe Lys Thr Gly Asp Lys Ile Ala Val Phe Ser Val Pro  
 85 90 95

ttt gat tgg aac tat tta tca aaa gga aaa gtc aca gca tat acc tat 336  
 Phe Asp Trp Asn Tyr Leu Ser Lys Gly Lys Val Thr Ala Tyr Thr Tyr  
 100 105 110

ggg gga ata aca ccc tac caa aaa act tca ata cct aaa aat atc cct 384  
 Gly Gly Ile Thr Pro Tyr Gln Lys Thr Ser Ile Pro Lys Asn Ile Pro  
 115 120 125

gtt aat tta tgg att aat gga aag cag atc tct gtt cct tac aac gaa 432  
 Val Asn Leu Trp Ile Asn Gly Lys Gln Ile Ser Val Pro Tyr Asn Glu  
 130 135 140

ata tca act aac aaa aca aca gtt aca gct caa gaa att gat cta aag 480  
 Ile Ser Thr Asn Lys Thr Thr Val Thr Ala Gln Glu Ile Asp Leu Lys  
 145 150 155 160

gtt aga aaa ttt tta ata gca caa cat caa tta tat tct tct ggt tct 528  
 Val Arg Lys Phe Leu Ile Ala Gln His Gln Leu Tyr Ser Ser Gly Ser  
 165 170 175

agc tac aaa agt ggt aga ctg gtt ttt cat aca aat gat aat tca gat 576  
 Ser Tyr Lys Ser Gly Arg Leu Val Phe His Thr Asn Asp Asn Ser Asp  
 180 185 190

aaa tat tct ttc gat ctt ttc tat gta gga tat aga gat aaa gaa agt 624  
 Lys Tyr Ser Phe Asp Leu Phe Tyr Val Gly Tyr Arg Asp Lys Glu Ser  
 195 200 205

atc ttt aaa gta tac aaa gac aat aaa tct ttc aat ata gat aaa att 672  
 Ile Phe Lys Val Tyr Lys Asp Asn Lys Ser Phe Asn Ile Asp Lys Ile  
 210 215 220

ggg cat tta gat ata gaa att gac tcc taa 702  
 Gly His Leu Asp Ile Glu Ile Asp Ser  
 225 230

<210> 2  
 <211> 233  
 <212> PRT  
 <213> *Streptococcus pyogenes*

<400> 2  
 Met Lys Lys Thr Lys Leu Ile Phe Ser Phe Thr Ser Ile Phe Ile Ala

|   |     |     |     |
|---|-----|-----|-----|
| 1   | 5   | 10  | 15  |
| Ile Ile Ser Arg Pro Val Phe Gly Leu Glu Val Asp Asn Asn Ser Leu |     |     |     |
| 20  |     | 25  | 30  |
| Leu Arg Asn Ile Tyr Ser Thr Ile Val Tyr Glu Tyr Ser Asp Ile Val |     |     |     |
| 35  | 40  | 45  |     |
| Ile Asp Phe Lys Thr Ser His Asn Leu Val Thr Lys Lys Leu Asp Val |     |     |     |
| 50  | 55  | 60  |     |
| Arg Asp Ala Arg Asp Phe Phe Ile Asn Ser Glu Met Asp Glu Tyr Ala |     |     |     |
| 65  | 70  | 75  | 80  |
| Ala Asn Asp Phe Lys Thr Gly Asp Lys Ile Ala Val Phe Ser Val Pro |     |     |     |
| 85  | 90  | 95  |     |
| Phe Asp Trp Asn Tyr Leu Ser Lys Gly Lys Val Thr Ala Tyr Thr Tyr |     |     |     |
| 100   | 105 | 110 |     |
| Gly Gly Ile Thr Pro Tyr Gln Lys Thr Ser Ile Pro Lys Asn Ile Pro |     |     |     |
| 115   | 120 | 125 |     |
| Val Asn Leu Trp Ile Asn Gly Lys Gln Ile Ser Val Pro Tyr Asn Glu |     |     |     |
| 130   | 135 | 140 |     |
| Ile Ser Thr Asn Lys Thr Thr Val Thr Ala Gln Glu Ile Asp Leu Lys |     |     |     |
| 145   | 150 | 155 | 160 |
| Val Arg Lys Phe Leu Ile Ala Gln His Gln Leu Tyr Ser Ser Gly Ser |     |     |     |
| 165   | 170 | 175 |     |
| Ser Tyr Lys Ser Gly Arg Leu Val Phe His Thr Asn Asp Asn Ser Asp |     |     |     |
| 180   | 185 | 190 |     |
| Lys Tyr Ser Phe Asp Leu Phe Tyr Val Gly Tyr Arg Asp Lys Glu Ser |     |     |     |
| 195   | 200 | 205 |     |
| Ile Phe Lys Val Tyr Lys Asp Asn Lys Ser Phe Asn Ile Asp Lys Ile |     |     |     |
| 210   | 215 | 220 |     |
| Gly His Leu Asp Ile Glu Ile Asp Ser                             |     |     |     |
| 225   | 230 |     |     |

&lt;210&gt; 3

&lt;211&gt; 705

&lt;212&gt; DNA

&lt;213&gt; Streptococcus pyogenes

&lt;220&gt;

&lt;221&gt; CDS

&lt;222&gt; (1)..(702)

&lt;400&gt; 3

atg aaa aca aac att ttg aca att atc ata tta tca tgt gtt ttt agc 48  
 Met Lys Thr Asn Ile Leu Thr Ile Ile Ile Leu Ser Cys Val Phe Ser  
 1 5 10 15

tat gga agt caa tta gct tat gca gat gaa aat tta aaa gat tta aaa 96.  
 Tyr Gly Ser Gln Leu Ala Tyr Ala Asp Glu Asn Leu Lys Asp Leu Lys  
 20 25 30

aga agt tta aga ttt gcc tat aat att acc cca tgc gat tat gaa aat 144  
 Arg Ser Leu Arg Phe Ala Tyr Asn Ile Thr Pro Cys Asp Tyr Glu Asn  
 35 40 45

gta gaa att gca ttt gtt act aca aat agc ata cat att aat act aaa 192  
 Val Glu Ile Ala Phe Val Thr Thr Asn Ser Ile His Ile Asn Thr Lys  
 50 55 60

caa aaa aga tcg gaa tgt att ctt tat gtt gat tct att gta tct tta 240  
 Gln Lys Arg Ser Glu Cys Ile Leu Tyr Val Asp Ser Ile Val Ser Leu  
 65 70 75 80

ggc att act gat cag ttt ata aaa ggg gat aag gtc gat gtt ttt ggt 288  
 Gly Ile Thr Asp Gln Phe Ile Lys Gly Asp Lys Val Asp Val Phe Gly  
 85 90 95

ctc cct tat aat ttt tcc cca cct tat gta gat aat att tat ggt ggt 336  
 Leu Pro Tyr Asn Phe Ser Pro Pro Tyr Val Asp Asn Ile Tyr Gly Gly  
 100 105 110

att gta aaa cat tcg aat caa gga aat aaa tca tta cag ttt gta gga 384  
 Ile Val Lys His Ser Asn Gln Gly Asn Lys Ser Leu Gln Phe Val Gly  
 115 120 125

att tta aat caa gat ggg aaa gaa act tat ttg ccc tct gag gct gtt 432  
 Ile Leu Asn Gln Asp Gly Lys Glu Thr Tyr Leu Pro Ser Glu Ala Val  
 130 135 140

cgc ata aaa aag aaa cag ttt act tta cag gaa ttt gat ttt aaa ata 480  
 Arg Ile Lys Lys Lys Gln Phe Thr Leu Gln Glu Phe Asp Phe Lys Ile  
 145 150 155 160

aga aaa ttt cta atg gaa aaa tac aat atc tat gat tcg gaa tcg cgt 528  
 Arg Lys Phe Leu Met Glu Lys Tyr Asn Ile Tyr Asp Ser Glu Ser Arg  
 165 170 175

tat aca tcg ggg agc ctt ttc ctt gct act aaa gat agt aaa cat tat 576  
 Tyr Thr Ser Gly Ser Leu Phe Leu Ala Thr Lys Asp Ser Lys His Tyr  
 180 185 190

gaa gtt gat tta ttt aat aag gat gat aag ctt tta agt cga gac agt 624  
 Glu Val Asp Leu Phe Asn Lys Asp Asp Lys Leu Leu Ser Arg Asp Ser  
 195 200 205

ttc ttt aaa agg tat aaa gat aat aag att ttt aat agt gaa gaa att 672  
 Phe Phe Lys Arg Tyr Lys Asp Asn Lys Ile Phe Asn Ser Glu Glu Ile  
 210 215 220

agt cat ttt gat atc tac tta aaa acg cac tag 705  
 Ser His Phe Asp Ile Tyr Leu Lys Thr His  
 225 230

<210> 4  
 <211> 234  
 <212> PRT  
 <213> *Streptococcus pyogenes*

<400> 4  
 Met Lys Thr Asn Ile Leu Thr Ile Ile Ile Leu Ser Cys Val Phe Ser  
 1 5 10 15

Tyr Gly Ser Gln Leu Ala Tyr Ala Asp Glu Asn Leu Lys Asp Leu Lys  
 20 25 30

Arg Ser Leu Arg Phe Ala Tyr Asn Ile Thr Pro Cys Asp Tyr Glu Asn  
 35 40 45

Val Glu Ile Ala Phe Val Thr Thr Asn Ser Ile His Ile Asn Thr Lys  
 50 55 60

Gln Lys Arg Ser Glu Cys Ile Leu Tyr Val Asp Ser Ile Val Ser Leu  
 65 70 75 80

Gly Ile Thr Asp Gln Phe Ile Lys Gly Asp Lys Val Asp Val Phe Gly  
 85 90 95

Leu Pro Tyr Asn Phe Ser Pro Pro Tyr Val Asp Asn Ile Tyr Gly Gly  
 100 105 110

Ile Val Lys His Ser Asn Gln Gly Asn Lys Ser Leu Gln Phe Val Gly  
 115 120 125

Ile Leu Asn Gln Asp Gly Lys Glu Thr Tyr Leu Pro Ser Glu Ala Val  
 130 135 140

Arg Ile Lys Lys Lys Gln Phe Thr Leu Gln Glu Phe Asp Phe Lys Ile  
 145 150 155 160

Arg Lys Phe Leu Met Glu Lys Tyr Asn Ile Tyr Asp Ser Glu Ser Arg  
 165 170 175

Tyr Thr Ser Gly Ser Leu Phe Leu Ala Thr Lys Asp Ser Lys His Tyr  
 180 185 190

Glu Val Asp Leu Phe Asn Lys Asp Asp Lys Leu Leu Ser Arg Asp Ser  
 195 200 205

Phe Phe Lys Arg Tyr Lys Asp Asn Lys Ile Phe Asn Ser Glu Glu Ile  
 210 215 220

Ser His Phe Asp Ile Tyr Leu Lys Thr His  
 225 230

<210> 5  
 <211> 711  
 <212> DNA  
 <213> *Streptococcus pyogenes*

<220>  
 <221> CDS  
 <222> (1)..(708)

<400> 5  
 atg aga tat aat tgt cgc tac tca cat att gat aag aaa atc tac agc 48  
 Met Arg Tyr Asn Cys Arg Tyr Ser His Ile Asp Lys Lys Ile Tyr Ser  
 1 5 10 15

atg att ata tgt ttg tca ttt ctt tta tat tcc aat gtt gtt caa gca 96  
 Met Ile Ile Cys Leu Ser Phe Leu Leu Tyr Ser Asn Val Val Gln Ala  
 20 25 30

aat tct tat aat aca acc aat aga cat aat cta gaa tcg ctt tat aag 144  
 Asn Ser Tyr Asn Thr Thr Asn Arg His Asn Leu Glu Ser Leu Tyr Lys  
 35 40 45

cat gat tct aac ttg att gaa gcc gat agt ata aaa aat tct cca gat 192  
 His Asp Ser Asn Leu Ile Glu Ala Asp Ser Ile Lys Asn Ser Pro Asp  
 50 55 60

att gta aca agc cat atg ttg aaa tat agt gtc aag gat aaa aat ttg 240  
 Ile Val Thr Ser His Met Leu Lys Tyr Ser Val Lys Asp Lys Asn Leu  
 65 70 75 80

tca gtt ttt ttt gag aaa gat tgg ata tca cag gaa ttc aaa gat aaa 288  
 Ser Val Phe Phe Glu Lys Asp Trp Ile Ser Gln Glu Phe Lys Asp Lys  
 85 90 95

gaa gta gat att tat gct cta tct gca caa gag gtt tgt gaa tgt cca 336  
 Glu Val Asp Ile Tyr Ala Leu Ser Ala Gln Glu Val Cys Glu Cys Pro  
 100 105 110

ggg aaa agg tat gaa gcg ttt ggt gga att aca tta act aat tca gaa 384  
 Gly Lys Arg Tyr Glu Ala Phe Gly Gly Ile Thr Leu Thr Asn Ser Glu  
 115 120 125

aaa aaa gaa att aaa gtt cct gta aac gtg tgg gat aaa agt aaa caa 432  
 Lys Lys Glu Ile Lys Val Pro Val Asn Val Trp Asp Lys Ser Lys Gln  
 130 135 140

cag ccg cct atg ttt att aca gtc aat aaa ccg aaa gta acc gct cag 480  
 Gln Pro Pro Met Phe Ile Thr Val Asn Lys Pro Lys Val Thr Ala Gln  
 145 150 155 160

gaa gtg gat ata aaa gtt aga aag tta ttg att aag aaa tac gat atc 528  
 Glu Val Asp Ile Lys Val Arg Lys Leu Leu Ile Lys Lys Tyr Asp Ile  
 165 170 175

tat aat aac cgg gaa caa aaa tac tct aaa gga act gtt acc tta gat 576  
 Tyr Asn Asn Arg Glu Gln Lys Tyr Ser Lys Gly Thr Val Thr Leu Asp  
 180 185 190

tta aat tca ggt aaa gat att gtt ttt gat ttg tat tat ttt ggc aat 624  
 Leu Asn Ser Gly Lys Asp Ile Val Phe Asp Leu Tyr Tyr Phe Gly Asn  
 195 200 205

gga gac ttt aat agc atg cta aaa ata tat tcc aat aac gag aga ata 672  
 Gly Asp Phe Asn Ser Met Leu Lys Ile Tyr Ser Asn Asn Glu Arg Ile  
 210 215 220

gac tca act caa ttt cat gta gat gtg tca atc agc taa 711  
 Asp Ser Thr Gln Phe His Val Asp Val Ser Ile Ser  
 225 230 235

&lt;210&gt; 6

&lt;211&gt; 236

&lt;212&gt; PRT

&lt;213&gt; Streptococcus pyogenes

&lt;400&gt; 6

Met Arg Tyr Asn Cys Arg Tyr Ser His Ile Asp Lys Lys Ile Tyr Ser  
1 5 10 15

Met Ile Ile Cys Leu Ser Phe Leu Leu Tyr Ser Asn Val Val Gln Ala  
20 25 30

Asn Ser Tyr Asn Thr Thr Asn Arg His Asn Leu Glu Ser Leu Tyr Lys  
35 40 45

His Asp Ser Asn Leu Ile Glu Ala Asp Ser Ile Lys Asn Ser Pro Asp  
50 55 60

Ile Val Thr Ser His Met Leu Lys Tyr Ser Val Lys Asp Lys Asn Leu  
65 70 75 80

Ser Val Phe Phe Glu Lys Asp Trp Ile Ser Gln Glu Phe Lys Asp Lys  
85 90 95

Glu Val Asp Ile Tyr Ala Leu Ser Ala Gln Glu Val Cys Glu Cys Pro  
100 105 110

Gly Lys Arg Tyr Glu Ala Phe Gly Gly Ile Thr Leu Thr Asn Ser Glu  
115 120 125

Lys Lys Glu Ile Lys Val Pro Val Asn Val Trp Asp Lys Ser Lys Gln  
130 135 140

Gln Pro Pro Met Phe Ile Thr Val Asn Lys Pro Lys Val Thr Ala Gln  
145 150 155 160

Glu Val Asp Ile Lys Val Arg Lys Leu Leu Ile Lys Lys Tyr Asp Ile  
165 170 175

Tyr Asn Asn Arg Glu Gln Lys Tyr Ser Lys Gly Thr Val Thr Leu Asp  
180 185 190

Leu Asn Ser Gly Lys Asp Ile Val Phe Asp Leu Tyr Tyr Phe Gly Asn  
195 200 205

Gly Asp Phe Asn Ser Met Leu Lys Ile Tyr Ser Asn Asn Glu Arg Ile  
210 215 220

Asp Ser Thr Gln Phe His Val Asp Val Ser Ile Ser  
 225 230 235

<210> 7  
 <211> 414  
 <212> DNA  
 <213> *Streptococcus pyogenes*

<220>  
 <221> CDS  
 <222> (1)..(411)

<400> 7  
 ctt ccg tac ata ttt act cgt tat gat gtt tat tat ata tat ggt ggg 48  
 Leu Pro Tyr Ile Phe Thr Arg Tyr Asp Val Tyr Tyr Ile Tyr Gly Gly  
 1 5 10 15

gtt aca cca tca gta aac agt aat tcg gaa aat agt aaa att gta ggt 96  
 Val Thr Pro Ser Val Asn Ser Asn Ser Glu Asn Ser Lys Ile Val Gly  
 20 25 30

aat tta cta ata gat gga gtc cag caa aaa aca cta ata aat ccc ata 144  
 Asn Leu Leu Ile Asp Gly Val Gln Gln Lys Thr Leu Ile Asn Pro Ile  
 35 40 45

aaa ata gat aaa cct att ttt acg att caa gaa ttt gac ttc aaa atc 192  
 Lys Ile Asp Lys Pro Ile Phe Thr Ile Gln Glu Phe Asp Phe Lys Ile  
 50 55 60

aga caa tat ctt atg caa aca tac aaa att tat gat cct aat tct cca 240  
 Arg Gln Tyr Leu Met Gln Thr Tyr Lys Ile Tyr Asp Pro Asn Ser Pro  
 65 70 75 80

tac ata aaa ggg caa tta gaa att gcg atc aat ggc aat aaa cat gaa 288  
 Tyr Ile Lys Gly Gln Leu Glu Ile Ala Ile Asn Gly Asn Lys His Glu  
 85 90 95

agt ttt aac tta tat gat gca acc tca tct agt aca agg agt gat att 336  
 Ser Phe Asn Leu Tyr Asp Ala Thr Ser Ser Ser Thr Arg Ser Asp Ile  
 100 105 110

ttt aaa aaa tat aaa gac aat aag act ata aat atg aaa gat ttc agc 384  
 Phe Lys Lys Tyr Lys Asp Asn Lys Thr Ile Asn Met Lys Asp Phe Ser  
 115 120 125

cat ttt gat att tac ctt tgg act aaa taa 414  
His Phe Asp Ile Tyr Leu Trp Thr Lys  
130 135

<210> 8  
<211> 137  
<212> PRT  
<213> *Streptococcus pyogenes*

<400> 8  
Leu Pro Tyr Ile Phe Thr Arg Tyr Asp Val Tyr Tyr Ile Tyr Gly Gly  
1 5 10 15

Val Thr Pro Ser Val Asn Ser Asn Ser Glu Asn Ser Lys Ile Val Gly  
20 25 30

Asn Leu Leu Ile Asp Gly Val Gln Gln Lys Thr Leu Ile Asn Pro Ile  
35 40 45

Lys Ile Asp Lys Pro Ile Phe Thr Ile Gln Glu Phe Asp Phe Lys Ile  
50 55 60

Arg Gln Tyr Leu Met Gln Thr Tyr Lys Ile Tyr Asp Pro Asn Ser Pro  
65 70 75 80

Tyr Ile Lys Gly Gln Leu Glu Ile Ala Ile Asn Gly Asn Lys His Glu  
85 90 95

Ser Phe Asn Leu Tyr Asp Ala Thr Ser Ser Ser Thr Arg Ser Asp Ile  
100 105 110

Phe Lys Lys Tyr Lys Asp Asn Lys Thr Ile Asn Met Lys Asp Phe Ser  
115 120 125

His Phe Asp Ile Tyr Leu Trp Thr Lys  
130 135

1/13

FIG 1

|        |           |             |            |            |            |            |    |
|--------|-----------|-------------|------------|------------|------------|------------|----|
| SMEZ   | -----     | -----       | LEVDNNSLPR | NIYSTIVYEV | SDTVIDEKVS | 30         |    |
| SMEZ-2 | -----     | -----       | LEVDNNSLPR | NIYSTIVYEV | SDIVIDEKVS | 30         |    |
| SPE-J  | -----     | -----       | -----      | -----      | -----      | -----      |    |
| SPE-C  | -----     | -----       | DSKK       | DISNVKSIDL | YATITPYDV  | KDCRVNESLT | 34 |
| SPE-G  | -----     | -----       | DE         | NLKDLKRSR  | FAVNITPCDV | ENVELAFVLT | 32 |
| SPE-H  | -----     | -----       | NSYN       | TTNRHMLESL | YKHDSNLIEA | DSIKNSPDIV | 34 |
| SEA    | SEKSEEINE | KDLRKKSSELQ | GAALQNLQI  | YYNEKAKTE  | NKESHDQFLQ | 49         |    |

a2

B1

|        |             |            |            |             |            |    |
|--------|-------------|------------|------------|-------------|------------|----|
| SMEZ   | ENLVTKKLDV  | RDARDFFINS | EMDEYAANDE | KDGCHIAMES  | VPFDWNLSE  | 80 |
| SMEZ-2 | ENLVTKKLDV  | RDARDFFINS | EMDEYAANDE | KTGCHIAMES  | VPFDWNLSE  | 80 |
| SPE-J  | -----       | -----      | -----      | -----       | LP...MIFT  | 6  |
| SPE-C  | ETLMNIDTQKY | RG.KDYYVIS | EMSYEASQKE | KRDCDVWVEG  | LF...XILN  | 79 |
| SpeG   | NSIKHINTKQK | RSECILYVDS | IVSLGITDQE | IKGDKVWVEG  | LF...XNFS  | 78 |
| SpeH   | TS.HML..KY  | .SVRKNLSV  | FFEKDWISQE | FKDKEDVLIYA | LSAQEVCE.. | 78 |
| SEA    | ETILFKGFFT  | NHSWYNDLLV | DFDSKDIVDK | YKGRNLVLYG  | AYYGYQCAGG | 99 |

B2

B3

a3

B4

|        |            |            |            |             |            |     |
|--------|------------|------------|------------|-------------|------------|-----|
| SMEZ   | GKVIAY.TY  | GWTPYQEE.. | PMISKNIEV  | WNRQDIPVE   | YEQISTNATT | 127 |
| SMEZ-2 | GKVTAW.TY  | GWTPYQKT.. | SILKNIPV   | WNGHOISVE   | YEQISTNATT | 127 |
| SPE-J  | RYDVVY.IY  | GWPSPVNSN  | SENSKIVG   | LIDGVQKTL   | IPPIKIDKPI | 54  |
| SPE-C  | SHTGEY.IY  | GWPSPAQN.N | KVNEBLLG   | FUSCESQQNL  | NEKUHLEKDI | 126 |
| SPE-G  | PPYVDN.IY  | GVKHSNQG   | NKSLQFVGIP | NQDGHETYLE  | SEAVRIKQKQ | 126 |
| SPE-H  | CPGKRM.EAF | GWLTNSEK   | .KEIRVPVNV | WDKSKHQ..E  | PMF TMDPK  | 124 |
| SEA    | TPNKTACM   | GVALHDNNRL | TEERKVEINL | WLD KQNTVIE | LETVKTAKKN | 149 |

B5

B6

B7

B8

|        |            |            |            |            |            |     |
|--------|------------|------------|------------|------------|------------|-----|
| SMEZ   | WIADELLRV  | KFLISQHQL  | SSGSSYKSG  | KIVFHNDNS  | DKYSQDILYV | 177 |
| SMEZ-2 | WIAQDILRV  | KFLIAQHQL  | SSGSSYKSG  | KIVFHNDNS  | DKYSQDILYV | 177 |
| SPE-J  | WIAQDILFKI | QYLMQTYKII | DATNSPYING | OPIAINGNK  | .RESFMYDA  | 103 |
| SPE-C  | WIAQDILFKI | KYQMDNWKI  | DATNSPYVSG | RIEIAGKDGK | .HEQDQEDDS | 175 |
| SPE-G  | WIAQDILFKI | KFLMEKQI   | DSESPRYVSG | SFLATKDK   | .HYEVHLENK | 175 |
| SPE-H  | WIAQDVLKRV | KULIKRQD   | NNR..EQKY  | SKGTWALDN  | SGKDIVFDLY | 172 |
| SEA    | WIAQDVLQ   | KYQEMQYNL  | NSDVFDGKV  | QRGLIVFHTS | TEPSVNYDLF | 199 |

B9

a4

B9

B10

|        |            |       |     |            |       |     |
|--------|------------|-------|-----|------------|-------|-----|
| SMEZ   | ..GYRDKEST | EWVZK | WSE | WIDKIGHLDI | EIDS  | 209 |
| SMEZ-2 | ..GYRDKEST | EWVZK | WSE | WIDKIGHLDI | EIDS  | 209 |
| SPE-J  | TSS.STRSDI | EWKVK | WSE | WMKDFSHFDI | WWTK  | 137 |
| SPE-C  | PNE.GTRSDI | EWKVK | WSE | WMKDFSHFDI | WPK   | 208 |
| SPE-G  | DDKLLSRDSF | EWKVK | WSE | WSEEISHFDI | WKRTH | 210 |
| SPE-H  | YFGNGDFNSM | EWKVK | WSE | DSTQF.HVDV | SIS   | 204 |
| SEA    | GAQQQNSNTL | LRTRP | WSE | WSENM.HIDU | WYTS  | 233 |

a5

B11

B12

## FIG 2

10

30

50

ATGAAAAAAACAAAACCTTATTTTTCTTTACTTCAATATTCAATTGCAATAATTCTCGT  
 M K K T K L I F S F T S I F I A I I S R

70

90

110

CCTGTGTTGGATTAGAAGTAGATAATAATTCCCTCTAAGGAATATCTATAGTACGATT  
 P V F G L E V D N N S L L R N I Y S T I

130

150

170

GTATATGAATATTCAGATATAGTAATTGATTTAAAACCAGTCATAACTTAGTACTAAG  
 V Y E Y S D I V I D F K T S H N L V T K

190

210

230

AAACTTGATGTTAGAGATGCTAGAGATTCTTTATTAACCTCCGAAATGGACCAATATGCA  
 K L D V R D A R D F F I N S E M D E Y A

250

270

290

GCCAATGATTTAAAACGGAGATAAAATAGCTGTGTTCTCCGTCCTTGGAAAC  
 A N D F K T G D K I A V F S V P F D W N

310

330

350

TATTTATCAAAGGAAAAGTCACAGCATATACCTATGGTGGAAATAACACCCCTACCAAAAA  
 Y L S K G K V T A Y T Y G G I T P Y Q K

370

390

410

ACTTCAATACCTAAAAAtCCCTGTTAATTATG GattaatGgAAAGcagatCTCTgtT  
 T S I P K N I P V N L W I N G K Q I S V

430

450

470

CcTtaCaaCGAAATATCaactAACAAACaacaGTTACAGCTCAAGAAAttgATCTAAAG  
 P Y N E I S T N K T T V T A Q E I D L K

490

510

530

GTTAGAAAATTTAATAGCACACATCAATTATATTCTCTGGTTCTAGCTACAAAGT  
 V R K F L I A Q H Q L Y S S G S S Y K S

550

570

590

GGTAGACTGGTTTTCATACAAATGATAATTCAAGATAATATTCTTCTGatcTTTctat  
 G R L V F H T N D N S D K Y S F D L F Y

610

630

650

gtagGATATAGAGATAAAGAAAGTATCTTAAAGTATACAAAGACAATAATCTTCAAT  
 V G Y R D K E S I F K V Y K D N K S F N

670

690

ATAGATAAAATGGGCATTTAGATATAGAAATTGACTCCTAA  
 I D K I G H L D I E I D S \*

3/13

SPE-G

## FIG 3

10

30

50

ATGAAAACAAACATTTGACAATTATCATATTATCATGTGTTTAGCTATGGAAGTCAA  
 M K T N I L T I I I L S C V F S Y G S Q

70

90

110

TTAGCTTATGCAGATGAAAATTAAAGATTTAAAAAGAAGTTAAGATTGCTATAAT  
 L A Y A D E N L K D L K R S L R F A Y N

130

150

170

ATTACCCCAGCGATTATGAAAATGTAGAAAATTGCATTGTTACTACAAATAGCATACT  
 I T P C D Y E N V E I A F V T T N S I H

190

210

230

ATTAATACTAAACAAAAAGATCGGAATGTATTCTTATGTTGATTCTATTGTATCTTA  
 I N T K Q K R S E C I L Y V D S I V S L

250

270

290

GGCATTACTGATCAGTTATAAAAGGGATAAGGTGATGTTGGTCTCCCTTATAAT  
 G I T D Q F I K G D K V D V F G L P Y N

310

330

350

TTTCCCCACCTTATGTAGATAATTTATGGTGGTATTGTAAAACATTGAATCAAGGA  
 F S P P Y V D N I Y G G I V K H S N Q G

370

390

410

AATAAAATCATTACAGTTGTAGGAATTTAAATCAAGATGGAAAGAAAACCTTATTTGCC  
 N K S L Q F V G I L N Q D G K E T Y L P

430

450

470

TctgAGGCTGTTCGATAAAAAGAAAACAGTTACTTACAGGAATttgATTTAAAATA  
 S E A V R I K K Q F T L Q E F D F K I

490

510

530

AGAAAATTTCTAATGGAAAAATACAATATCTATGATTGGAATCGCGTTATACATCGGGG  
 R K F L M E K Y N I Y D S E S R Y T S G

550

570

590

AGCCTTTCTTGCTACTAAAGATAGTAAACATTATGAAGTTGATTATTTAATAAGGAT  
 S L F L A T K D S K H Y E V D L F N K D

610

630

650

GATAAGCTTTAAGTCGAGACAGTTCTTAAAAGGTATAAGATAATAAGATTTAAT  
 D K L L S R D S F F K R Y K D N K I F N

670

690

AGTGAAGAAATTAGTCATTTGATATCTACTTAAAACGCACTAG  
 S E E I S H F D I Y L K T H \*

4/13  
SPE-H FIG 4

10 30 50

ATGAGATATAATTGTCGCTACTCACATATTGATAAGAAAATCTACAGCATGATTATATGT  
M R Y N C R Y S H I D K K I Y S M I I C

70 90 110

TTGTCATTCTTTATATTCCAATGTTGTCAGCAAATTCTTATAATACAACCAATAGA  
L S F L L Y S N V V Q A N S Y N T T N R

130 150 170

CTAAATCTAGAACATCGCTTATAAGCATGATTCTAATTGATTGAAGCCGATAGTATAAAA  
H N L E S L Y K H D S N L I E A D S I K

190 210 230

AATTCTCCAGATATTGTAACAAGCCATATGTTGAAATATAGTGTCAAGGATAAAAATTG  
N S P D I V T S H M L K Y S V K D K N L

250 270 290

TCAGTTTTTTGAGAAAGATTGGATATCACAGGAATTCAAAGATAAAGAAGTAGATATT  
S V F F E K D W I S Q E F K D K E V D I

310 330 350

TATGCTCTATCTGCACAAGAGGTTGTGAATGTCCAGGGAAAAGGTATGAAGCGTTtggt  
Y A L S A Q E V C E C P G K R Y E A F G

370 390 410

GGAATTACATTAACTAATTAGAAAAAAAAGAAATTAAAGTTCTGTAAACGtgtGggat  
G I T L T N S E K K E I K V P V N V W D

430 450 470

AAAAGTAAACAAACAGCCGCCTATGTTATTACAGTCATAAAACCGAAagtaaCCGCTCAG  
K S K Q Q P P M F I T V N K P K V T A Q

490 510 530

GAAGTGGATATAAAAGTTAGAAAGTTATTGAttaagaaatacgATATCTATAATAccgg  
E V D I K V R K L L I K K Y D I Y N N R

550 570 590

gaacaaaaatactctaaaggaactgttaccttagATTAAATTCAAGGTAAAGATATTGTT  
E Q K Y S K G T V T L D L N S G K D I V

610 630 650

TTTGATTGTATTATTTGGCAATGGAGACTTAATAGCATGCTAAAATATATTCCAAT  
F D L Y Y F G N G D F N S M L K I Y S N

670 690 710

AACGAGAGAATAAGactcaactCAATTCATGTAGatgTGTcaatcagctaA  
N E R I D S T Q F H V D V S I S \*

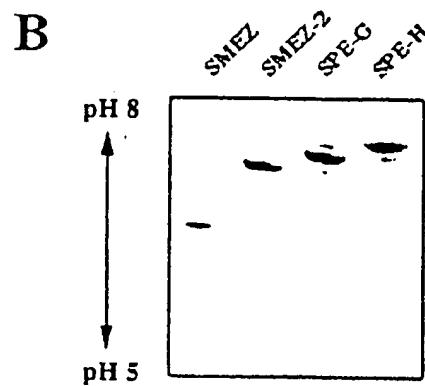
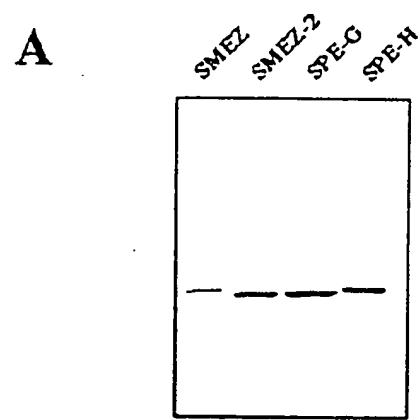
SPE-J (partial)

5/13  
FIG 5

|   |     |     |
|---|-----|-----|
| 10  | 30  | 50  |
| CTTCCGTACATATTTACTCGTTATGATGTTATTATATATGGTGGGGTTACACCATCA     |     |     |
| L P Y I F T R Y D V Y Y I Y G G V T P S                       |     |     |
| 70  | 90  | 110 |
| GTAAACAGTAATTGGAAAAATAGTAAAATTGTAAGGTAAATTACTAATAGATGGAGTCCAG |     |     |
| V N S N S E N S K I V G N D L I D G V Q                       |     |     |
| 130   | 150 | 170 |
| CAAAAAACACTAATAAAATCCCATAAAATAGATAAACCTATTTTACGATTCAAGAATT    |     |     |
| Q K T L I N P I K I D K P I F T I Q E F                       |     |     |
| 190   | 210 | 230 |
| GACTTCAAAATCAGACAATATCTTATGCAAACATAACAAAATTATGATCTAATTCTCCA   |     |     |
| D F K I R Q Y L M Q T Y K I Y D P N S P                       |     |     |
| 250   | 270 | 290 |
| TACATAAAAGGGCAATTAGAAAATTGCGATCAATGGCaATAAACATGAAAGTTAACCTTA  |     |     |
| Y I K G Q L E I A I N G N K H E S F N L                       |     |     |
| 310   | 330 | 350 |
| TATGATGCAACCTCATCTAGTACAAGGAGTGATATTTAAAAAAATATAAAGACaATAAG   |     |     |
| Y D A T S S S T R S D I F K K Y K D N K                       |     |     |
| 370   | 390 | 410 |
| ACTATAAAATGAAAGATTCAGCCATTGATATTTACCTTggACTAAATAA             |     |     |
| T I N M K D F E S H F D I Y L W T K *                         |     |     |

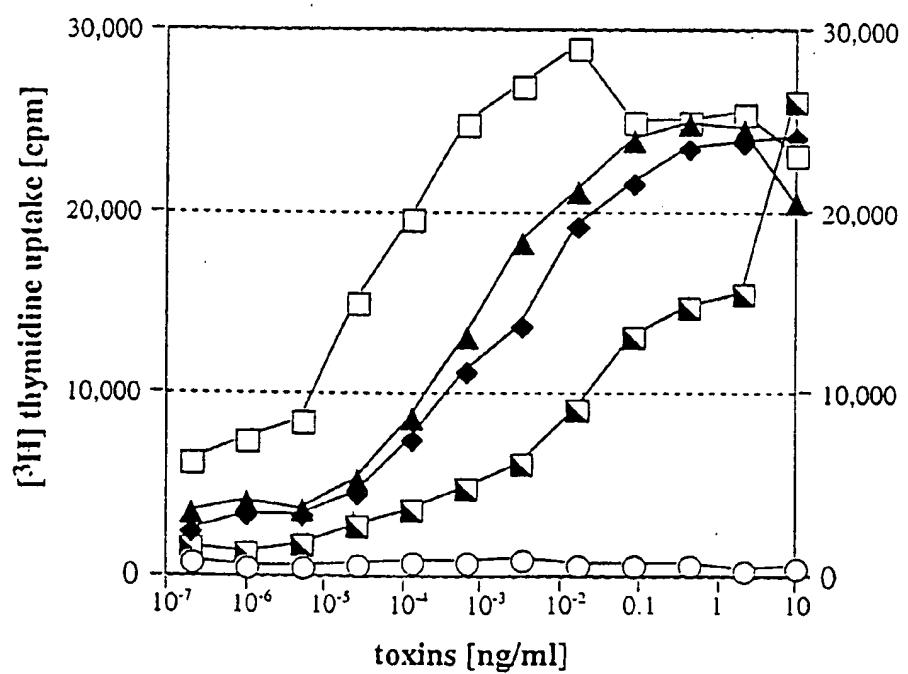
6/13

FIG 6



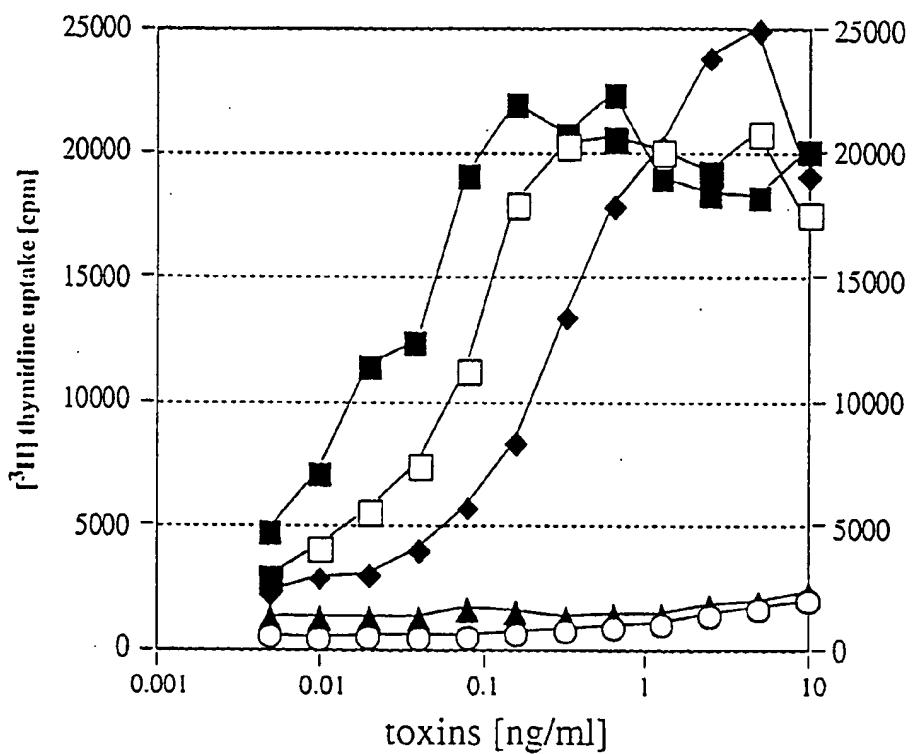
7/13

FIG 7



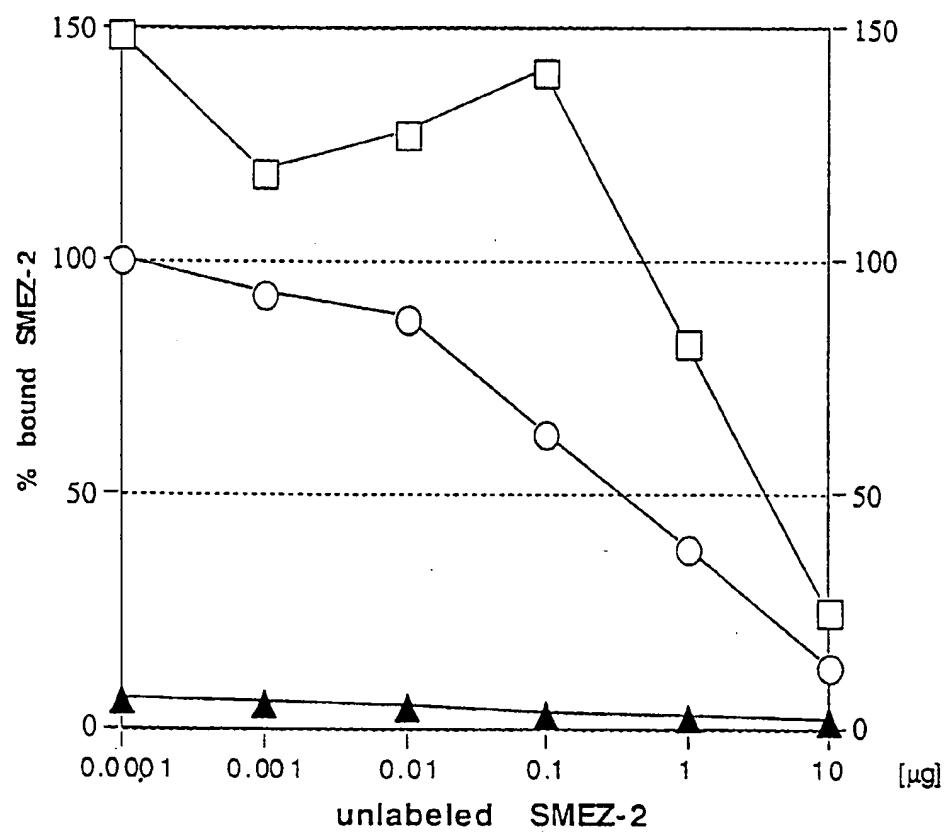
8/13

FIG 8



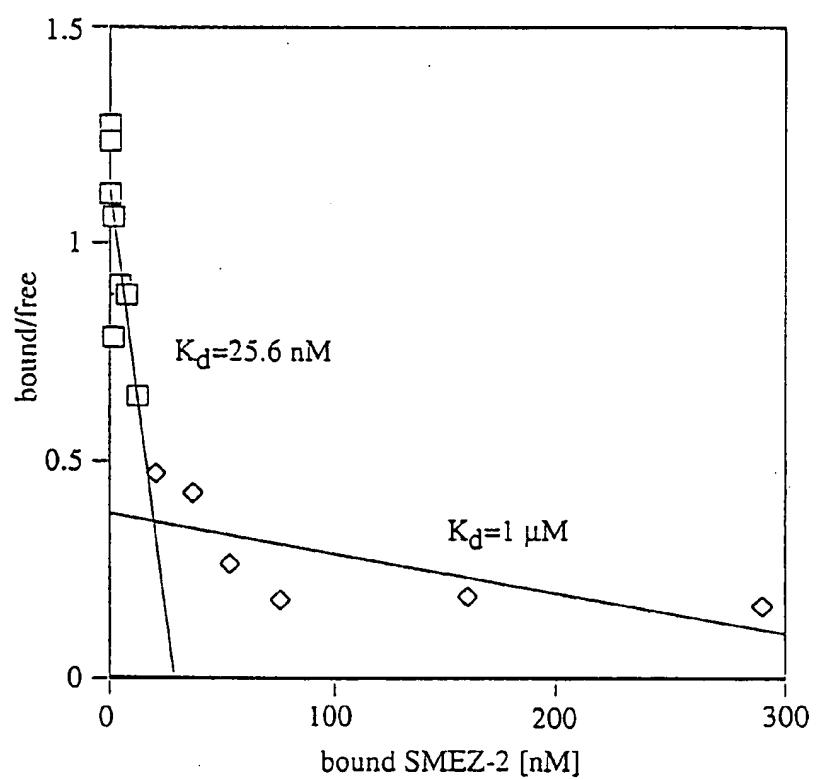
9/13

FIG 9



10/13

FIG 10



11/13

FIG 11

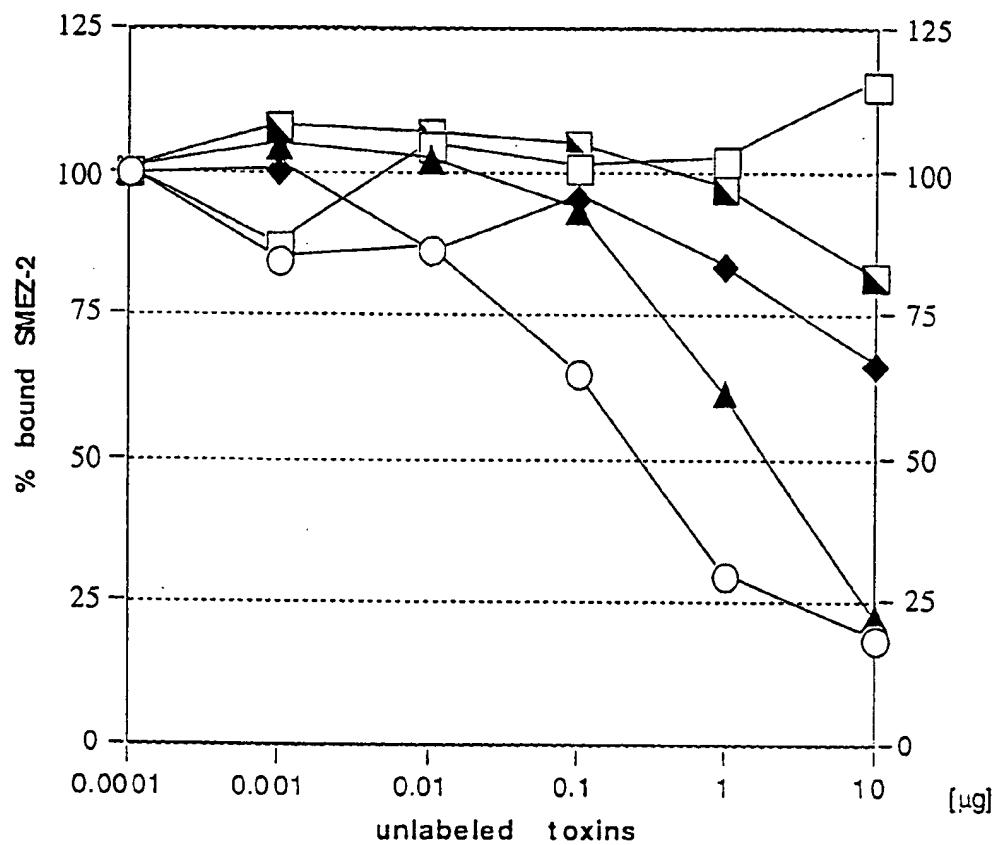
unlabeled toxins

|        | SMEZ | SMEZ-2 | SPE-G | SPE-H | SEB | TSST | SEA  | SPE-C |
|--------|------|--------|-------|-------|-----|------|------|-------|
| SMEZ   | █    | █      | □     | □     | □   | □    | █    | ████  |
| SMEZ-2 | █    | █      | □     | □     | □   | □    | █    | □     |
| SPE-G  | █    | ████   | █     | □     | □   | □    | ████ | ████  |
| SPE-H  | █    | █      | □     | █     | □   | □    | █    | █     |
| SEB    | □    | □      | □     | □     | █   | □    | ████ | □     |
| TSST   | ████ | ████   | □     | □     | □   | █    | █    | ████  |
| SEA    | □    | ████   | □     | ████  | □   | □    | █    | □     |
| SPE-C  | ████ | □      | □     | □     | □   | □    | █    | █     |

tracer toxins

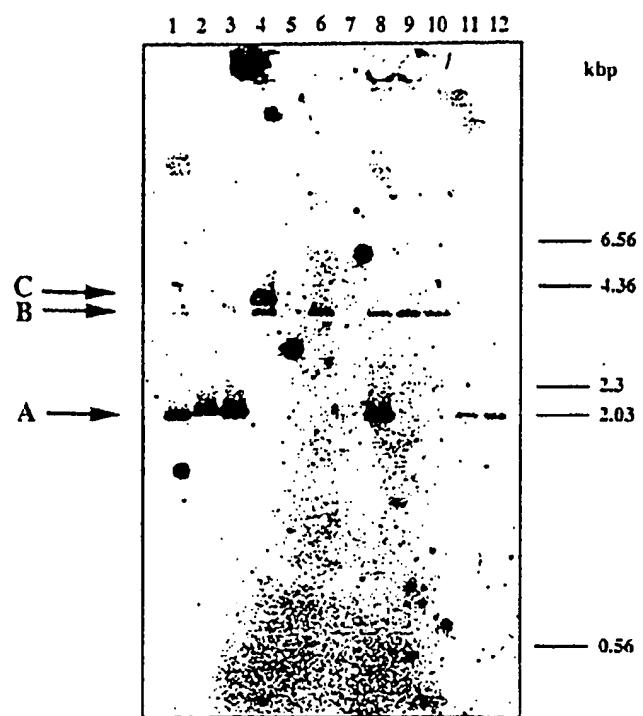
12/13

FIG 12



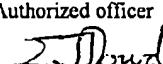
13/13

FIG 13



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NZ99/00228

|  |   |                                   |
|--|---|-----------------------------------|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b>   |   |                                   |
| Int. Cl. 7: C07K 14/315, C07K 16/12, C07H 19/00, C12N 1/20, C12Q 1/68, A61K 35/74, A61K 39/09  |   |                                   |
| According to International Patent Classification (IPC) or to both national classification and IPC  |   |                                   |
| <b>B. FIELDS SEARCHED</b>  |   |                                   |
| Minimum documentation searched (classification system followed by classification symbols)  |   |                                   |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  |   |                                   |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>STN: File WPIDS Keywords used: "superantigen or super(w) antigen" and "streptococ?"<br>ANGIS Database: Sequence ID No's 2, 4, 6, and 8.  |   |                                   |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>  |   |                                   |
| Category*  | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No.             |
| P,X  | Journal of Experimental medicine (1999) 189(1), 89-101<br>"Identification and characterization of novel superantigens from <i>Streptococcus pyogenes</i> " Proft, T et al | 1-30                              |
| P,X  | Database GenPept, Accession No. CAB51744, Authors: Gerlach, D, Wagner, M, Fleischer, B, Schmidt, KH, Vettermann, S, Reichardt, W.<br>Submitted 29 July 1999.              | 1, 2, 6, 7, 14-20, 24, 25, 29, 30 |
| P,X  | Database GenPept, Accession No. CAB51332, Authors: Gerlach, D, Wagner, M, Fleischer, B, Schmidt, KH, Vettermann, S, Reichardt, W.<br>Submitted 19 July 1999.              | 1, 2, 6, 7, 14-20, 24, 25, 29, 30 |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex  |   |                                   |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed |   |                                   |
| Date of the actual completion of the international search<br><b>XX March 2000</b>  | Date of mailing of the international search report<br><b>- 8 MAY 2000</b>   |                                   |
| Name and mailing address of the ISA/AU<br><br>AUSTRALIAN PATENT OFFICE<br>PO BOX 200, WODEN ACT 2606, AUSTRALIA<br>E-mail address: pct@ipaaustralia.gov.au<br>Facsimile No. (02) 6285 3929   | Authorized officer<br><br><b>IAN DOWD</b><br>Telephone No : (02) 6283 2273            |                                   |

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NZ99/00228

| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |  |   |
|---|--|---|
| Category*   | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No.                         |
| P,X   | Database GenPept, Accession No. CAB51142, Authors: Gerlach, D, Wagner, M, Fleischer, B, Schmidt, KH, Vettermann, S, Reichardt, W.<br>Submitted 19 July 1999.                                 | 1, 2, 6, 7, 14-20, 24, 25, 29, 30             |
| X   | Infection and Immunity (1998) 66(7), 3337-3348<br>" Identification and Characterization of Staphylococcal Enterotoxin Types G and I from <i>Staphylococcus aureus</i> "<br>Munson, SH et al. | 1, 2, 6, 7, 14-20, 24, 25, 29, 30             |
| X   | Molecular Microbiology (1998) 29(2), 527-543<br>"The gene for toxic shock toxin is carried by a family of mobile pathogenicity islands in <i>staphylococcus aureus</i> ". Lindsay, JA et al. | 1, 2, 6, 7, 14-20, 24, 25, 29, 30             |
| X   | Infection and Immunity (1998) 56(9), 2518-2520<br>" Nucleotide Sequence of Streptococcal Pyrogenic Exotoxin Type C"<br>Goshorn, SC and Schlicvert, PM.                                       | 1, 5, 12-20, 23, 24, 28-30                    |
| X   | Database Swiss-Prot, Accession No. SPEC_STRPY<br>& Infection and Immunity (1998) 56(9), 2518-2520<br>& Infection and Immunity (1992) 60: 3513-3517<br>& Nat Struct Biol (1997) 4: 635-643    | 1, 5, 12-20, 23, 24, 28-30                    |
| X   | Database GenPept, Accession No. AAB 59091,<br>& Infection and Immunity (1998) 56(9), 2518-2520<br>& Infection and Immunity (1992) 60: 3513-3517  | 1, 5, 12-20, 23, 24, 28-30                    |
| P,X   | WO 99/27889 (10June 1999) IDAHO RESEARCH FOUNDATION INC<br>See claim 3 in particular.  | 1, 3, 4, 8-11, 14-19, 21-22, 24, 26-27, 29-30 |

INTERNATIONAL SEARCH REPORT  
Information on patent family members

International application No.  
PCT/NZ99/00228

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent Document Cited in Search Report | Patent Family Member |
|--|----------------------|
| WO 99/27889                            |                      |

END OF ANNEX